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New England Water Works Association

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OUTLINE OF THE SPRINGFIELD WATER WORKS.

BY ELBERT E. LOCHRIDGE.*

[*Read September 27, 1932.*]

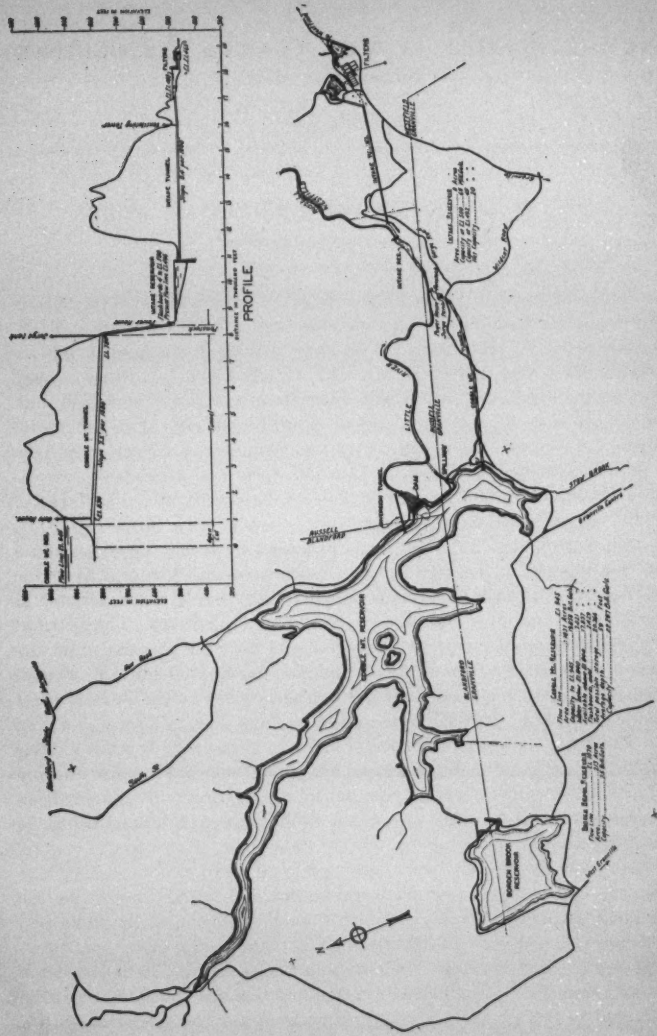
There has recently come to light the act of incorporation of the Springfield Aqueduct filed with the Commonwealth of Massachusetts in 1798. The records of the following meetings show that there was immediately installed in the village of Springfield a water supply which apparently covered the area then settled. This supply came from springs in the nearby hills which have since become populated areas within the city. It is not my intention to carry this history through the development of the earlier supplies of the period before the city took over the works and developed areas entirely outside of the city to supply the growing population. I shall rather confine myself to the present works.

Since 1910, the Little River has furnished water for the city under a new development in compliance with modern needs. The growth of the city has been rapid from that date. Practically all of the conditions of water supply were given a part in the plans then undertaken. The distribution system was enlarged and reinforced, and not only was the water delivered under heads which would give ample pressure, but the sizes were so designed that the pressure could be maintained even at the rates of draft experienced during extensive fires and other large uses.

The water comes from an area of high elevation sparsely settled and is of natural purity. A quality standard was established and is maintained by a slow sand-filtration plant augmented by coagulation and sedimentation as necessary. These earlier developments have been described before to this Association.

The new development (see accompanying map) is the working out along the same lines of a complete system, maintaining and improving the standards already set in such a manner that the full value of the watershed is secured. Capacities of the filtration plant, transmission mains, and clear-water storage have been increased in order to care for the needs of a much larger community. There has been no extension of watershed area, but the additional works include a storage reservoir at Cobble Mountain with a capacity of 22 800 m.g. which, with the reservoir on Borden Brook already

*Chief Engineer, Springfield Water Works, Springfield, Mass.



GENERAL PLAN OF COBBLE MOUNTAIN DEVELOPMENT, SPRINGFIELD WATER WORKS.

in service, gives a total capacity of 25 300 m.g. on an area of 48.5 sq. miles. This capacity is sufficient to control and store the complete run-off from this area. Due to the steep character of the stream, a very high dam was necessary to secure this storage. The succeeding paper by Mr. Hatch, Division Engineer in charge of the Cobble Mountain development, gives a few features of this large structure and discusses some of the problems involved in its construction.

The site for storage of this water is but 1½ miles from the point of diversion of the stream for city use, and inasmuch as the flow line is 456 ft. higher than the point of diversion, this head is used for the generation of electric power, the wheels discharging into the diversion reservoir which has been in use for the past 23 years. This development differs from one, by which regular quantities of water may be taken each day; or, as in many cases, must be taken each day or be lost to the plant. The power plant is so designed that through the wet seasons when power is plentiful, only the actual quantities of water needed for city consumption are drawn from the reservoir, leaving the stored waters for use during the dry season when hydro-electric plants dependent upon river flow are short of power. Mr. Moody, in his paper, outlines the operation of this plant, which is leased by the Turners Falls Power & Electric Company, of which he is the Hydraulic Engineer. This development has involved the construction of a pressure tunnel 1½ miles in length, drawing water directly from the depths of the reservoir at Cobble Mountain and delivering it, after its use for power, directly into the city supply. The surge tank and power plant at the outlet end of the tunnel are additional structures which have been built in this development.

When the waters were first taken from Little River, diversion was made by means of a tunnel substantially one mile in length, with an ultimate capacity of about 35 m.g.d., which seemed at that time to be the full capacity of the stream. The new development raises the safe yield of the stream to about 55 m.g.d. with an average annual rate of flow of about 62 m.g.d.

The utilization of water in its first stage for power brought the new problem of its time of use. In order that the best utilization of the water for power during the peak-load hours should not interfere with the constant demand of the filtration plant for drinking-water production over a 24-hour period, the intake tunnel was extended in an enlarged section at each end and its capacity raised, thus permitting the most effective development for both power and water supply, without loss of water. In the line of this tunnel, two Venturi meters, one 6-ft. the other 3-ft. in diameter, are arranged in parallel in such a way that the diversions from the stream are taken automatically to the sedimentation basin just above the filters, and its capacity constantly maintained at whatever rate the water is available. Fluctuations in this rate of diversion have been as high during one day as from five m.g.d. to more than 100 m.g.d. The stored water not needed

in any year for water-supply purposes, but provided for future water-supply needs, is drawn by the power company during the season when it is most advantageous to do so.

Additional clear-water storage at Provin Mountain is made available by the construction of a new covered concrete reservoir with a capacity of 12 m.g. This with the present reservoir will raise the clear-water storage to 29 m.g. This reservoir, located 8 miles from the West Parish Filters and 4½ miles from the city, takes the water as it is delivered from the enlarged filtration plant, which is described by Mr. Salmond. It, also, acts as a standpipe which, together with the additional new 54 to 48-in. pipe line from the clear-water reservoir to the city, maintains a full head under the varying uses of the Metropolitan district. Water is admitted to these reservoirs through a much-needed new aërator of 264 nozzles.

My outline in no way completes the description of the various features to which a good deal of time could be given, but is intended only as an introduction to the papers which follow.

Many inquiries have come in regarding the financing of the new works and to the coördination of the different uses. The right to generate power is leased to the Turners Falls Power & Electric Company for $270 000 a year, with adjustments after the city has doubled its present use of water. The bonds for all of the additional structures are issued on the basis of an equalization of payments in each of the 30 years; that is, the retirements and interest are equal in each of those years, the interest being the larger portion during the earlier years, and the retirements being the larger portion during the later years. With 4-per cent. bonds, this means a payment of about 5.8 per cent. for both interest and retirement. The revenue received will carry and retire the construction cost of the development for additional water.

CONSTRUCTION OF THE COBBLE MOUNTAIN DAM OF THE SPRINGFIELD WATER WORKS.

BY HARRY H. HATCH.*

[*Read September 27, 1932.*]

Location. The Cobble Mountain dam is located in the narrow gorge of the Little River at the foot of the northern slope of Cobble Mountain in Western Massachusetts. The new reservoir impounded by it occupies the site of a glacial reservoir of some millions of years ago. Cobble Mountain Reservoir has a capacity of 22.83 billion gallons and an area of 1 134 acres.

Dimensions and Quantities. The dimensions of the dam (See Fig. 1) are given in the following schedule:

	Feet.
Length at base	62
Width at base	1 510
Length at top	730
Width at top	50
Average upstream slope	3 to 1
Average downstream slope	3½ to 1
Height of center above original river bed	243
Maximum height at center above foundation	263
Freeboard above top of flashboards	21
Upper rock-toe—Width	424
Height, maximum	106
average	90
Lower rock-toe—Width	448
Height, maximum	95
average	64
Thickness of riprap, maximum	15
minimum	2
Elevation of top, above sea level	973

The work of constructing the dam consisted of the following:

1. Clearing and grubbing dam site ..... 13 acres

2. Excavation in Foundation	Cubic Yards. Earth.	Rock.
Cut-off trench	4 496.1	9 391.6
Concrete toe-wall	1 220.3	1 042.4
Core area	8 591.2	.....
Shoulder area	24 407.5	.....
Total	38 715.1	10 434.0

*Division Engineer, in charge of Cobble Mountain Reservoir, Springfield Water Works, Springfield, Mass.

3. Fill	Cu. yd.	Per cent.
(a) Concrete cut-off walls	1 292	.07
(b) Concrete toe-wall	3 747	.21
(c) Grout in cut-off trench	231	.01
(d) Upper rock-toe	148 671	8.26
(e) Lower rock-toe	144 218	8.01
(f) Hydraulic fill in shoulders	1 176 419	65.39
(g) Hydraulic fill in core	209 500	11.65
(h) Dry fill near top	13 890	.77
(i) Upper riprap	70 197	3.91
(j) Lower riprap	31 001	1.72
Grand Total	1 799 166	100.00
Sub Totals		
Concrete and grout (a, b, c)	5 270	.3
Rock (d, e, i, j)	394 087	21.9
Earth (f, g, h)	1 399 809	77.8

Spillway. The spillway is located on the southern slope of Cobble Mountain at a distance of about 1 500 ft. from the dam. It is an open cut excavation through solid rock with a total length of 735 ft. and a maximum depth of 55 ft. The crest is 135 ft. wide, narrowing within a distance of 200 ft. to a width of 50 ft. The bell-mouth section, 200 ft. long, has an average slope of 8.5 per cent.; the balance has a slope of 1 per cent. The spillway excavation ends 265 ft. above the river bed, which is about 2 900 ft. downstream from the lower toe of the dam. At a distance of 170 ft. downstream from the crest, there is a reinforced concrete bridge over the spillway channel. The channel bottom and sides are lined with concrete from the crest to a point past the bridge.

The spillway is provided with 7-ft. high flashboards supported by 5-in. diameter wrought-iron pipes from 2 ft.–10 in. to 4 ft.–1 in. on centers.

Main items of the spillway construction consisted of:

	Cu. yd.
Earth excavation	22 298.7
Rock excavation	48 109.9
Concrete	4 490.3

The material from the earth and rock cuts in the spillway were used as fill in the dam. Discharge experiments were conducted with models, one fiftieth actual size, of the original and succeedng designs for the spillway. Observations during experiments suggested certain changes in the design to obviate dead and negative velocities especially along the sides of the channel. The spillway was constructed according to the third design after operation of its model gave satisfactory results.

Cut-off Trench Excavation. Near the upstream limits of the core area, a cut-off trench was excavated in order to secure the best possible sealing of the rock foundation with fine core material. The cut-off trench was 80 ft.

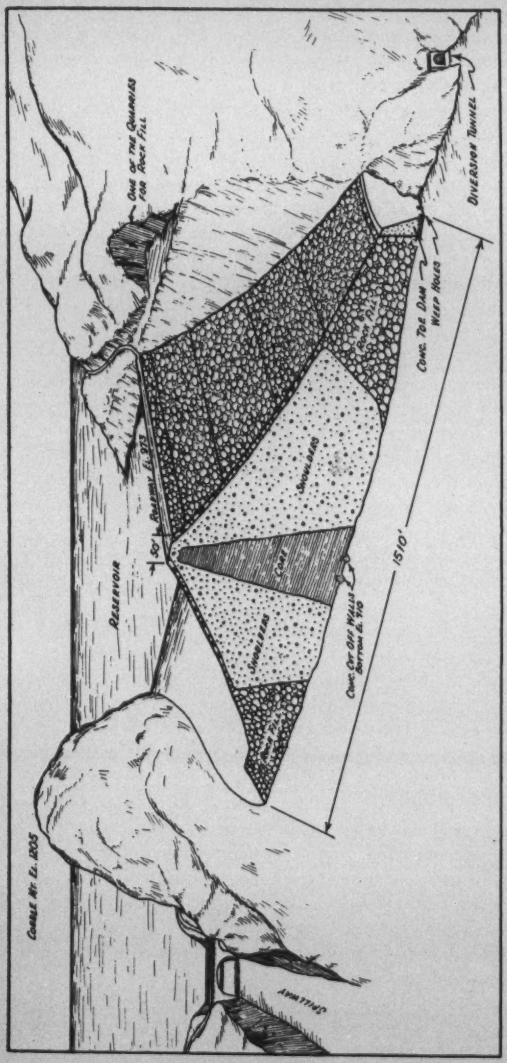


FIG. 1. — GENERAL FEATURES OF COBBLE MOUNTAIN DAM.

wide in the bed of the stream, and gradually narrowed down to 20 ft. on the slopes of the dam site at elevation 955, near the top of the dam. The trench was carried to a minimum depth of 5 ft. in solid rock, and deeper whenever necessary in order to reach sound rock. The average depth of the cut-off trench at the bottom is 20 ft. below the river-bed elevation.

The ground was so rough and the narrow gorge so steep that it was almost impossible to do the excavation by machinery. All the earth excavation was done by hand. Jackhamers were used for drilling the rock. Shooting was done in small lots, the muck always being handled by hand. Derricks were set up at convenient places and a few short tracks built at different elevations from the center of the dam to the upper and lower rock fills. Skips were loaded by hand and hoisted with the derricks and unloaded into dump cars. The muck trains were either pushed by hand or moved by lines from hoisting engines. The muck was placed within the outlines of the rock toes of the dam.

Concrete Toe-Wall Excavation. Both the earth and rock excavations in the foundation of the concrete toe-dam were handled similar to the cut-off trench operations. Here, the excavations for the abutments were carried down to sound solid rock. There was no rock excavation in foundation at the bottom, where the structure rested on the original rock surface.

Excavation Within the Core Area. In order to insure a good bond between the hydraulic fill and the sides of the gorge, particular care was taken especially within the core area to remove all surface cover.

The excavation within the maximum core limits on the side slopes was made by stripping-monitors mounted in the core pool, or by jets from independent pipe lines, or by hand.

It was soon discovered that if the surface cover within the core section was sluiced into the core pool, the fines would disperse all over the core area and leave the coarse material next to the sides of the gorge, creating blind drains. All such coarse deposits next to the sides were removed, and later all the excavation was carried away from the core area onto the beaches. All crevices and pockets were cleaned of dirt within the minimum core limits.

Excavation Within the Shoulder Areas. All surface cover within the shoulder areas was excavated either dry or by water. In some cases deep pockets were encountered, and it became necessary to use small steam shovels or draglines to remove heavy deposits of earth. The material thus excavated was spread all over the beach either by draglines, or hauled and dumped in separate piles by Linn trucks so that the sluicing pipes would discharge directly onto it in order to wash the fines into the core, leaving the coarse material on the beach.

Concrete Cut-Off Walls. Along the center line of the cut-off trench there is a 3 ft. by 3 ft. concrete cut-off wall, with a foundation of minimum width of 3 ft. and a minimum depth of 5 ft. in the bottom of the cut-off trench. This wall extends all the way across the bottom and up on each

side of the gorge to elevation 955, within a few feet of the top of the dam.

Thirty feet upstream there is another similar cut-off wall within the cut-off trench, except that it does not extend to near the top of the dam but stops on both sides of the gorge at elevation 765.

Concrete mixers and aggregate bins were placed on the slopes at sufficiently high locations. The concrete was mixed in half-yard batches, and shot to the bottom in steel and wooden chutes. Occasionally, however, the nearby derricks with buckets were used to place concrete where the chutes could not reach.

Concrete Toe Wall. This is a 100-ft. radius concrete arch dam, with a maximum length of 189 ft. Its width is 14 ft. at the top and about 30 ft. at the bottom. Its height above the original river bed is 35 ft. and above the foundation 50 ft. The structure has three 4 ft. by 6 ft. weep holes to take care of drainage in the lower slope of the dam. (See Fig. 2.)

The mixing plant and the aggregate bins were located on the south slope of the gorge about 150 ft. above the concrete dam. Two half-yard batch mixers were operated, sometimes by steam and sometimes by compressed air, with a maximum output of about 200 yards a day. Here, also, the concrete was shot down into the forms by means of metal and wooden chutes. Occasionally derrick buckets were used to carry the concrete to farther corners of the structure.

Grout. In order to seal the crevices in the rock at the bottom and sides of the core, the cut-off trench area was grouted. Along the bottom of the cut-off wall foundation trench, 102 grout holes, each 15 ft. deep, were drilled at about 10 ft. intervals. The depth of the holes was measured from the bottom of the foundation trench. Grout pipes 2 in. in diameter and long enough to extend above the cut-off walls, were inserted in the grout holes to a depth of about 12 in. This 12-in. section was sealed so as not to permit any concrete to penetrate into the grout holes. In the bottom of the cut-off trench there were also eight grout holes, each 25 ft. deep.

Grouting was done during the time the concrete cut-off wall was poured and allowed to reach final set. The grout contained from three to ten parts of water to one part of cement. No sand was used. A 7-cu. ft. grout machine operated by air was used.

Grouting was started at the lowest holes and proceeded thence to higher elevations. As a rule, the ungrouted holes were not closed so that they could act as air vents. Grouting was started at a pressure of 10 lb. per sq. in. and was gradually increased to 40 lb. per sq. in. No grout hole was considered completed until it refused to take grout at a pressure of 40 lb. per sq. in.

Some of the grout holes took as many as 198 bags of cement, or 1 285 cu. ft. of grout.

Rock Fill. There are nearly 395 000 cu. yd. of loose rock in the toes and riprap of the dam. The diversion dam, which constitutes part of the upper rock toe, contains about 56 000 cu. yd. of rock and was completed

FIG. 2. — CONCRETE TOE WALL LOOKING DOWNSTREAM.
Note outlet of diversion tunnel in central background.

FIG. 3. — DIVERSION TUNNEL UNDER CONSTRUCTION.

under a separate contract in 1928 in connection with the construction of the diversion tunnel. This structure includes about 15 000 cu. yd. of tunnel muck (See Fig. 3). The balance of rock was quarried by open-cut methods in near-by locations at least 100 ft. away from the outline of the main dam. Ordinary jackhamer drilling and shooting were employed. Almost all of the rock was handled by small, $\frac{5}{8}$-cu. yd. bucket, steam shovels and transported on old fashioned tip carts.

For the remaining 339 000 cu. yd. of loose rock, there were available in the foundation of the dam 10 434 cu. yd. and in the spillway 48 110 cu. yd. of solid rock, aggregating 87 816 cu. yd. of loose rock. It became necessary to borrow about 252 000 cu. yd. of loose rock or 168 000 cu. yd. of solid rock, as it was found that one cubic yard of solid rock excavation yielded 1.5 cu. yd. of loose rock. For this borrow material, quarries were established at convenient places near the dam site. More than a dozen small tunnels about 4 ft. square were driven. They usually had branches at the end of the adit. Depending on the weight or yardage of rock above the tunnels, charges up to 16 tons of dynamite were placed within and exploded. The general averages of these various tunnels show that for every foot of tunneling, about 135 cu. yd. of rock were obtained, and for every pound of explosive there was a yield of $1\frac{3}{4}$ cu. yd. of loose rock.

A few tunnels, in the early stages of construction, were driven and shot with the intention of placing rock directly into final position in the rock toes of the dam.

Some of the rock was side cast from the borrow-pit floor into place at the bottom of the dam by $1\frac{3}{4}$-cu. yd. steam shovels. A small amount was hauled and dumped by trucks directly into final position, but considerable yardage was dumped by trucks onto ramps from which it was later cast and recast into place.

All riprap rock was hauled by trucks and dumped directly in place.

Hydraulic Fill. The hydraulic fill method was employed in placing practically all of the earth fill in Cobble Mountain Dam.

Two methods were followed in the hydraulic operations:

(a) All operations performed by water; i.e., the material was excavated, transported, and placed in the dam by water.

(b) Material brought dry to dam site and placed by water; i.e., the material was excavated by shovels, hauled by trains to dissolving boxes and thence placed in the dam by water.

All Operations Performed by Water. A total of 159 254 cu. yd. of hydraulic fill in the lower 65 ft. of the dam were placed by entirely hydraulic operations. (See Fig. 4.) In the borrow pits near the dam, the material was excavated by means of three 5-in. hydraulic giants supplied with enough water under sufficient pressure to break up the soil and carry the excavated material mixed with water into 20-in. steel pipes, the so-called "mud lines," leading to the dam. The water was brought to the borrow pits from the nearby river by means of 28-in. steel pipes and two,

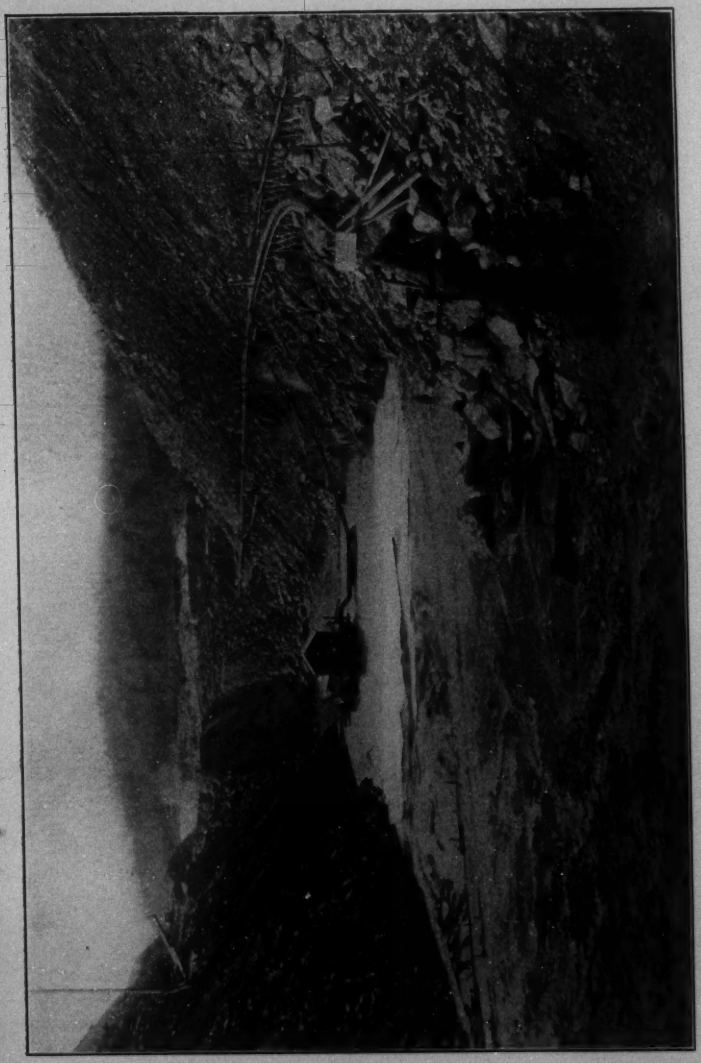


FIG. 4. — SLUICING MATERIAL INTO THE DAM DURING EARLY STAGES OF CONSTRUCTION.

and sometimes three, 650-h.p. electrically driven pumps. The flow in the mud lines consisted of about 7.5 per cent. of solid material and 92.5 per cent. of water. Mud-line slopes of less than 4 per cent. caused the pipes to clog. (See Fig. 5.)

Near the dam site, the mud line from the borrow pits was divided, by means of a Y and hand-operated gates, into two lines leading to the upper and lower beaches. The material was deposited on one beach at a time. The mud lines extended across the gorge parallel to the center-line of the dam along the outer edges of the beaches.

The beaches were generally raised gradually from one side of the gorge to the other by taking out a length of pipe at regular intervals of time and

FIG. 5. — GIANTS AT WORK IN THE BORROW PIT.

changing the point of discharge of the mud line uniformly from one side to the other. While sluicing was taking place on one beach, the pipe line on the other beach was laid at a higher elevation and made ready for the next sluicing.

Water probably is one of the most important factors in full hydraulic-fill construction. The amount of water used in the operation will depend not only on the yardage of fill per day, but also on the percentage ratio of the load carried to the water required. On the basis of a 7.5 per cent. load, the placing of 10 000 cu. yd. of hydraulic fill in a day will require 25 m.g.d. of water. In order to save this water at Cobble Mountain, and to meet sanitary restrictions downstream from the dam, it was necessary to operate on a closed circuit. The water and material discharged from the mud lines near the shoulders of the dam eventually reached the core pool in the middle of the dam. One or more pumps on a pontoon pumped the muddy water from the core pool into the supply pool or supply lines feeding

the giants at the borrow pits. Thus the same water was used over and over again. Whenever it was necessary to replenish the water in the core pool, a fresh supply of water was obtained from the nearby river.

On each beach, a ½-cu. yd. dragline excavated gravel near the discharge point and placed it back of the pipe line, thus building the outer slope of the dam in the shape of a dike. This dike also prevented water and material from running down the outer slope of the dam.

At the end of the sluicing ditches near the entrance to the mud lines, grizzlies prevented stones larger than about 8-in. in diameter from getting into the pipe lines. These larger stones in addition to boulders too large to

FIG. 6. — DISSOLVING BOX. EMPTY TRAIN PULLING OUT. GIANTS AT WORK.

be moved by the action of water, were left in the bottom of the borrow-pit area. Due to horizontal and vertical bends in the long pipe line from the borrow pit to the dam, large stones would not only cause clogging of the lines, but also exert much wear and tear upon the pipe in a short time.

The larger and heavier the particles carried, the more quickly will the pipes wear out. Fine sand and clay will give maximum life. Steep slopes and high velocities will decrease it. Depending on the material, slope, and velocities, the service of a steel pipe will vary from 100 000 to about 2 000 000 cu. yd.

It was discovered that bends and breaches wore out first. The pipes do not fail at the same time, neither do they have uniform wear. Local defects in the metal and in the joints give away first. Worn spots are immediately repaired in the field. The bottom of a pipe line wears out the quickest. The pipes are given a quarter turn as necessity requires until there is a complete wearing of the entire pipe shell.

One advantage of complete hydraulic fill operations is that animal labor is cut down to a minimum. Everything is done by machinery, power, and water. Rain, muddy roads, or soft track beds cannot influence operation. No meteorological conditions will stop operations unless the ground is frozen so hard and the weather is so cold that satisfactory construction becomes impossible.

Material Brought Dry to Dam Site and Placed in Dam by Water. A total of 1 236 815 cu. yd. of hydraulic fill in the next 195 ft. of the dam was excavated by shovels in borrow pits, hauled by trains and dumped into dissolving boxes at the dam site, thence placed in the structure by water. (See Fig. 6.) At the borrow pits there were three $1\frac{3}{4}$-cu. yd. dipper steam shovels digging and loading the material onto 4-cu. yd. side dump cars. There were 9 trains, each with 10 cars, hauled by 20-ton gasoline engines over 36-in. gage double-track railway lines. The maximum length of track from the borrow pits to the dam was 9 000 ft., with a maximum curvature of 40 deg. and a maximum grade of 7.2 per cent. for empties and 2.5 per cent. up-grade for loaded trains.

Placed at different elevations and locations during construction, there were two dissolving boxes, made of timber with sheet-metal bottom and sides. They were 150 ft. long, 19 ft. wide, and 8 ft. deep so that a ten-car trainload could be dumped at once and about six train loads could be piled up.

Pumps mounted on pontoons in the core pool (Fig. 7) supplied the necessary pressure and volume of water to the two 5-in. giants placed at each end of the dissolving box. These giants washed the material from the box leading into the mud lines extending to the beaches or shoulders of the dam.

In this method also the water was used in a closed circuit. The core-pool water was replenished from the nearby river, by means of pumps and 6-in supply lines, one on each side of the gorge. The supply lines were also used for stripping the soil cover of the dam site, and the water used in this manner served also to replenish the core pool.

All material excavated from the borrow pits was brought to the hog box. This box had a 28-in. outlet leading into a 48-in. electric-driven sheet-metal grizzly 16 ft. long, with openings varying from 6 to 10 in. The grizzly revolved at 8 r.p.m. The large stones that did not pass through the 28-in. outlet were removed by a derrick and piled near the hog box to be carried away later. Under the grizzly a 5 ft. by 7 ft. hopper had outlets leading to the lower and upper-beach mud lines. The rocks held in the grizzly were discharged into a rock chute extending onto the beach. The rock piles at the end of this chute on the beach were scattered, at intervals, over the beach area by means of drag lines.

Aside from the grizzly and the rock chutes, the placing of the material in the dam from the dissolving box onward, was entirely similar to the full hydraulic operations.

The maximum rate of placing material in the dam was 2 500 cu. yd. per shovel per 10-hour shift. The general average per working day was 7 100 cu. yd. of hydraulic fill placed in the dam. A total of 969 575 cu. yd. of material was placed in one season.

Near the top of the dam, above the maximum water level in the reservoir, hydraulic placing was stopped on account of the small width of the dam, the lack of sufficient slope in the mud lines, and the necessity of raising the dissolving box. The railroad tracks were extended along the

FIG. 7. — SLUICING NEAR TOP OF DAM. DISSOLVING BOX ON SOUTH SIDE OF DAM.

The diagonal pipe line on the right is for replenishing the water in the core pool. To the left of pump houses can be seen the rock chute and the rock pile which was later spread all over the beach.

core pool on the shoulders of the dam. The material was dumped from the cars directly into the pool. The pool was replenished as the water was absorbed by the fresh dry material. By gradual raising and throwing of the tracks, the pool was caused to disappear and the dam was topped. (See Fig. 8.)

Organic Matter. Care was taken not to have any organic matter left in the structure. All roots, sod, and vegetation that were deposited on the beaches were picked up and carried away. The fine organic matter that went into the core pool formed a scum on the surface of the pool. Special crews in boats collected the scum, before it had a chance to settle to the bottom of the core pool, and hauled it away.

Borrow Pits. Before the structure was designed, a systematic investigation was made of all the available material near the dam site. Beginning at the dam, test pits were dug in all directions. The samples ob-

tained were tested in the laboratory, and the quantities of the deposit were estimated. Approved borrow-pit areas were designated with proper quality and more than sufficient quantity of material for the hydraulic-fill construction of the dam. The borrow material had a specific gravity of 2.72, and came from glacial deposits consisting of clean sand, gravel, and sufficient fines to make a satisfactory core.

Control. The engineer should have a thorough knowledge of the functions of the constituent parts of a hydraulic-fill dam under construction. It is often impossible to obtain, without undue delay in the progress of the

FIG. 8. — TOPPING OF THE DAM.

work, ideal conditions as laid out in the specifications for the construction of the various sections of the dam. It is a real problem to build a dam satisfactorily without handicapping the contractor who, as a rule, is only concerned with the amount of fill deposited in the structure. Constant watch should be exercised both at the borrow pits and the dam to see that without cutting down the efficiency of plant output the quality of the structure is not affected.

The function of the beaches is to support, during construction, the liquid or semi-liquid core with heavier specific gravity than water. The beach, therefore, must be not only heavy enough to resist this pressure, but also porous enough to drain.

The more uniform the particle size of the beach material, the higher will be the percentage of voids. This results in less weight in the structure and lessens its resistance both during and after construction. A better

gradation or uniform variation in size, will result in smaller percentage of voids of the beach material. The smaller the percentage of voids of the beach material, the stronger is the structure.

The function of the core section of a dam is to stop the passage of water through it. There is no earth dam, so to speak, absolutely watertight. They all leak more or less, and the seepage through a hydraulic-fill dam will depend on the many characteristics of the core material. Among them is the particle size of the core material; the smaller the core material particle size, the longer will it take to settle, drain, and consolidate, and vice versa. Other things being equal, a core of finer or smaller particle size will leak less than one with larger core materials. It is evident that the core material must contain particles coarse enough to allow the required drainage and consolidation, and yet fine enough to minimize seepage. A combination of fine and coarse materials in the core will give a smaller percentage of voids, resulting in less seepage. Other things being equal, the coefficient of permeability in the core section will vary nearly as the 6th power of the percentage of voids and as the square of the effective size of its material.

Variation of Particle Sizes and Percentage of Voids of Material in the Cross Section of Cobble Mountain Dam.

	West Beach Sections.					East Beach Sections			
	4	3	2	1	Core	1	2	3	4
Effective Size in m.m.	..	.100	.068	.020	.009	.020	.054	.075	..
Number of Samples Tested	..	55	47	103	765	91	31	39	..
Percentage of Voids	28.2	36.7	41.5	..	..	..	41.8	36.8	30.0
Number of Samples Tested	7	43	23	..	..	..	19	27	7

In the above table each beach is divided into four sections:

1 represents the area between the maximum and minimum limits of the core,
2 is adjacent to maximum core limits,
3 is the middle third, and
4 is the outer third of the beach near the slopes of the dam.

During construction much of the drainage in the core will take place vertically; yet eventually drainage will also take place horizontally. This, and also the seepage when the reservoir is full, will vary as the path of percolation or the width of the core at any elevation of the dam.

From the above considerations it can easily be seen that with a change in the character of the core material, the prescribed core section can be changed without affecting the function of the core.

With finer core material a narrower core pool can be allowed, while with coarser material, a wider core pool must be maintained within certain limits.

The presence of organic matter is objectionable both in the beach and the core, as it will tend to decrease the unit weight and the coefficient of permeability of the material in the structure.

The control in the construction of hydraulic-fill dams with respect to beach and core sections is more or less automatic. If the borrow material

contains excessive fines, the core will build up faster than the beach section, thus resulting in a shallow core-pool. If, on the other hand, the material from the borrow pit does not contain sufficient fines, the beach will build up faster than the core section, resulting in a deep core-pool.

There is a limit to this variation in core-pool depth. It was found that when the core pool is less than 4 ft. deep, the suction of the core-pool pump is affected by pumping fines to the giants in the dissolving box or at the borrow pits. Very deep core pools are objectionable, especially in the higher sections of the dam where the beaches get narrower. The deeper and wider the core pool, the shorter will become the beach sections; and some of the failures during construction are due to the core pool not being under proper control.

While the deposit in the borrow pits, taken as a whole, may be perfectly satisfactory for the construction of the dam, any one location in the borrow pit may possess an original gradation of material which will not necessarily be satisfactory for construction of the dam. Especially in glacial deposits, pockets of uniform large stones, gravel, fine sand, rock flour, and very fine materials are often encountered. A rightly proportioned mixture of these materials will be required, and no one material alone should be constantly sent from the borrow pit to the structure. Care should be exercised at the borrow pit so that the various shovels, or giants, are working in deposits which will yield a material satisfactory for the construction of the dam. The material of construction should be controlled in the borrow pit without depending on the more or less automatic control of the hydraulic fill operations.

As the dam material is discharged from the mud line, the larger particles settle out first, and then smaller and smaller particles until the very fines go to the core pool. At least this is the theory, which is supported by practice almost exactly, depending on the velocity of flow, particle size of solid material, slope of beaches, quantity of discharge, and depth of core pool.

As the material flows down the beaches, provided there is enough depth of water in the core pool, it is checked as soon as it strikes the water; the larger particles will then sink immediately and only the very fine ones remain suspended in the water. The very fine particles held in suspension will ultimately settle and make up the core, or the watertight section of the dam.

Beginning with the core, as a rule, towards the outer slopes of the dam section, the particle sizes are larger, the coefficient of permeability is more, and the percentage of voids is smaller.

Concentrated flows on the beach will cut channels and carry coarse particles into the core section, causing sloughing. To prevent this, shear boards are placed near the discharge of the pipe to spread the flow uniformly over a section of the beach.

The coarse material in the core section can be moved out and spread

over the beach areas by means of draglines. The material which the dragline cannot reach can be agitated and dispersed among the fines of the core section by means of a jetting apparatus mounted on a floating platform on the pool.

Excess depth in the core pool will result in extra width. It was found by experience that the width of the core pool is the governing factor of the width of the core. When, at any one elevation, the pool is wider than the core section, at that elevation a wider core will be constructed.

Raising the beach too much at one time will result in widening of the core pool on the opposite side. Even though this additional width is very shallow, it will contain fine particles in suspension which will settle on the beach. This action, of course, will depend also on the percentage of fines contained in the sluiced material and on the velocity of flow and the slope of the beach. With excessive fines, flat beach slopes, and slow velocities in the discharge, fines will deposit over the entire beach. These fines will prevent drainage and will act as a lubricating plane for movement of the beach material.

In the alternate sluicing, from one beach at a time, the pool outline will be moved back and forth. As a rule, on the side where the sluicing is taking place the beaches will be built to the proper core limits at that elevation, but on the other side the water will be pushed back over the beach. Provided there is enough velocity to the flow and enough slope to the beach, the fines deposited outside the core section on the other beach will be washed into the core.

Excessive fines are objectionable, especially on a construction where the fines cannot be wasted down the river. Some 35 000 cu. yd. of material with excessive fines was brought to the dam from other than prescribed borrow pits. The deposit containing excessive fines was located very near the dam site at a higher elevation so that the material could be brought over to the dam by gravity with sufficient slope. In every respect except for the fines, this location was desirable. Due to the sanitary restrictions, the filter plant, and paper mills down below the dam, it was impossible to waste the excessive fines, and a closed circuit scheme was adopted for using the water over again. Immediate difficulty was encountered, as the core section built up so much faster than the beach that there was hardly enough water in the core pool to float the core pumps. It became almost impossible to operate the plant due to the fines being carried back and forth and due to the wear and tear on the pumps on account of the fines. Extensive studies were made to provide special storage basins for depositing the excessive fines. After much thought and time spent on the proposition, the idea was given up and the structure was built from the materials in the original prescribed borrow-pit areas.

Tests and Record Plans. Painstaking tests and records should be made during the construction, and their data should be kept conscientiously. There is so much variation in the characteristics of the material from the

beginning to the end of construction that a few tests made during the construction for any one particular purpose does not necessarily represent average values for the structure.

The Cobble Mountain Dam was built during 1927 to 1932 by the Springfield Board of Water Commissioners, with E. E. Lochridge as Chief Engineer, the late Allen Hazen as Consulting Engineer, and the writer as Division Engineer in charge of construction.

THE WEST PARISH FILTRATION PLANT OF THE SPRINGFIELD WATER WORKS.

BY HERBERT F. SALMOND.*

[*Read September 27, 1933.*]

The West Parish Filtration Plant of the Springfield Water Works is located in the western part of Mundale, a suburb of Westfield, situated in the westerly part of that town, 14 miles from Springfield. The plant up to date consists of a control house, a tunnel connecting it with a sedimentation basin, a laboratory building, an aërator, ten slow sand-filters, three entrance houses to the six old filters (one to each pair of filters), a regulator house, a service building, a sand court for the old filters, eight sand bins for the new filters, and a pressure reservoir. Owing to the location of the plant, houses are provided for the chemist, superintendent and foreman, and a reservoir serves the plant with pure water.

A mile west of the filtration plant, in the so-called "gorge," is the diversion dam which forms the intake reservoir. Water from this reservoir is diverted to the filtration plant through a tunnel 5 356 ft. long with a cross-section 6 ft. 3 in. in height and 5 ft. in width. This tunnel is capable of delivering up to 100 m.g.d. of water.

Design Features.

The control house, situated at the easterly portal of the tunnel leading from the gorge, contains two Dow valves and Venturi meters and two alum-feed machines, all of which have automatic devices for their regulation. This building provides plenty of storage space for the chemicals needed.

A second tunnel, 730 ft. in length, and equivalent to a 6.5-ft. pipe, connects the control house with the sedimentation basin. This basin has an area of 10 acres, a depth of 31 ft. and a capacity of 42.04 m.g. It is kept filled by the automatic valves in the control house.

The laboratory building houses on its second floor the chemical and bacteriological laboratories, and offices for the chemist and superintendent. On the first floor, there is a power room containing a turbine with a slow-speed, 35-k.w. generator which supplies the power needed at the plant.

The aërator, which is 50 ft. in diameter and about 10 ft. deep, contains two fountains, with diameters of 18 and 24 in. respectively, and an outlet for the turbine. Two 42-in. steel pipes connect this aërator with the old and new filters.

The ten filter units have a total filtering area of 6¼ acres. (See

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Figure 1.) All units are 260 ft. long and 12 ft. high. The six old filters are 91 ft. wide, as against 143 ft. for the four new ones. The old units each have an area of 0.5 acre; the new ones, each have an area of 0.8 acre. A centrally located main drain runs the length of each filter, 20 pairs of lateral drains entering it from the side. The lateral tile drains are covered to a depth of 7 in. with gravel retained on a 1-in. mesh screen. Following this come 2.5 in. of gravel or broken stone which passes a 1-in. screen and is retained on a $\frac{3}{8}$-in. screen. Then come 2.5 in. of gravel or broken stone that passes a $\frac{3}{8}$-in. screen and having an effective size of between 2 and 3 mm., is coarser than ordinary sand. Covering this gravel are

FIG. 1. — WEST PARISH FILTER PLANT. SETTLING BASIN IN LEFT BACKGROUND.

42 in. of sand which has an effective size of 0.3 mm. and a uniformity coefficient of about 2.3. The pressure and sand pipes are attached to the long walls of the filters. (See Fig. 2.)

A sand court, 182 ft. by 52 ft. and 3 ft. in depth placed on top of parts of filters 3 and 4, together with eight cylindrical sand bins, each with a diameter of 34 ft. and a depth of 22.5 ft. placed south-east of the old filters, give ample room for the storage of sand.

The regulator house contains the wet well, meters, and gates for the old filters. The service building contains the wet well, entrances, and controlling devices for the new filters, together with a tool shop. A triplex pressure pump, motor and generator are located in the basement to supply water for sand washing.

The pressure reservoir on the hill opposite the filter beds has an outlet elevation of 716 ft. above sea level. This cylindrical structure

has a diameter of 60 ft., a depth of 26 ft. and a capacity of 400 000 gal. and supplies water with a pressure of 110 lb. per sq. in. at the filters.

The operating force, which acts under the supervision of the Chief Engineer, consists of a chemist, superintendent, foreman, mechanic, seventeen laborers, and two watchmen.

The superintendent is in charge of the cleaning and operating of the filters and has general supervision over the grounds and buildings. The chemist devotes his time to the daily chemical and bacteriological analyses

FIG. 2. — WEST PARISH FILTER PLANT. PLACING SAND AND GRAVEL IN FILTER BED.

and supervises the chemical treatment of the water. The foreman oversees the laborers at work. The mechanic makes whatever repairs become necessary in a plant of this size. Fifteen of the laborers scrape and rake filters, and take care of the grounds as required, while one assists the chemist and one acts as teamster. Two watchmen alternate between four o'clock in the afternoon until 7.30 the next morning.

Water enters the sedimentation basin from the river by way of the tunnels and control house, where its flow is regulated by automatic gates. The amount of water passing is recorded by two Venturi meters. After a storage period of between two and three days in the sedimentation basin, the water passes onto the filters either through the turbine located on the first floor of the laboratory building or by way of the two fountains in the aërator in front of the laboratory building. This aërator controls

the height of the water in the filters. A weir in the aërator acts as an overflow above elevation 465 ft. The effluent of each filter is regulated by a gate in the wet-well houses. Each effluent pipe contains a Venturi meter; gages are located in the wet-well rooms. The filtered effluent passes through a 42-in. steel pipe for a distance of 7.4 miles to Provin Mountain Reservoir and thence to the city as needed.

Operating Features.

In the care of the filters, there are two alternating processes: scraping and raking. When a filter is first put into commission it is run at a rate of 3 m.g.d. per acre corresponding to 1½ m.g. for each of the old filters and 2½ m.g. for each of the new. When the loss of head has reached 6 ft., the filter is cut off, drained, scraped, or raked. Experience has taught us that it is inadvisable, with our type of water, to rake more than once between scrapings. In scraping a filter usually 1½ in. of surface sand are scraped off and cleaned. In this process, two portable boxes, 15-in. deep and 22-in. by 28-in. in plan, containing ejectors having an 0.7-in. nozzle and a 1.25-in. throat, set 2.25-in. apart, are placed in the filter and connected by means of 3-in. hose with the pressure and sand lines, which are on the walls of the filters. It requires eight men with a foreman in charge to clean a filter. The men scrape and shovel the sand into the boxes, which are moved from place to place, as needed. The old filters require an extra man on the sand court. From the ejectors the sand is conveyed to two stationary washers, located at either end of the sand court for the old filters and in the service building for the new ones. The sand from the old washers is ejected into the sand court and into the sand bins from the new. In raking a filter, the bed is drained and raked in one day by two men in case of an old unit and by three in case of a new one. In refilling a filter, water from an adjoining unit is allowed to backfill into the filter through the under-drains until a foot of water stands over the sand. Then the influent valve under the stairs is opened and the filter is allowed to fill gradually from above. The length of time ordinarily required to scrape an old filter and prepare it for refilling is about one and one-half working days or twelve hours; for a new filter, the time is about two working days or sixteen hours. A filter generally refills over night. The amount of sand removed per 1½-in. scraping equals 105 cu. yd. for an 0.5-acre filter, and 220 cu. yd. for an 0.8-acre bed. At times, it is necessary to remove two inches of sand.

Operating Results.

During the past five years, 1927–1931 inclusive, the average annual number of scrapings has been 21.8 for the old filters and 12.4 for the new. The average length of run per scraping is 93.34 m.g. for the old filters and 155.94 m.g. for the new. During the same period, the average number

TABLE 1.—AVERAGE RUNS AFTER SCRAPING AND RAKING.

Year.	Old Filters 1–6.				New Filters 7–10.			
	Scrapings.		Rakings.		Scrapings.		Rakings.	
	No.	Ave. Run m.g.	No.	Ave. Run m.g.	No.	Ave. Run m.g.	No.	Ave. Run m.g.
1927	18	106.58	19	75.01	7	166.80	7	134.39
1928	17	93.78	13	78.07	8	153.54	9	157.32
1929	24	73.92	15	96.84	15	146.62	7	140.39
1930	21	110.48	7	69.81	17	171.21	3	110.28
1931	29	81.92	13	56.24	15	141.51	8	97.40
Total	109	466.68	67	375.97	62	779.68	34	639.78
Average	21.8	93.34	13.4	75.19	12.4	155.94	6.8	127.96

TABLE 2.— COST OF CLEANING.

Year.	Scraping.			
	No. of Scrapings.	Cu. Yd. of Sand Cleaned.	Cost of Cleaning. $	Cost per Cu. Yd. $
1927	27	4 115	2 218.60	0.539
1928	24	5 620	2 349.65	0.418
1929	38	8 170	3 822.40	0.468
1930	30	7 230	3 175.60	0.437
1931	46	11 455	4 572.65	0.399
Total				2.261
Average				0.45

Year.	Re-Sanding.			
	No. of Re-Sandings.	Cu. Yd. of Sand Replaced.	Cost of Re-Sanding. $	Cost per Cu. Yd. $
1927	2	4 205	921.35	0.219
1928	1	2 940	495.80	0.169
1929	3	8 740	1 876.95	0.215
1930	3	9 180	2 190.15	0.239
1931	3	10 500	2 002.10	0.190
Total				1.032
Average				0.21

of rakings has been 13.4 for the old filters, with an average run of 75.19 m.g. per raking, and 6.8 for the new filters with an average run of 127.96 m.g. per raking.

When by scraping the depth of sand in a filter has been reduced to 20 in., all sand is removed in order to prevent subsurface clogging. The first three inches are scraped and put through the washers in the usual manner. The remaining sand is shovelled into the ejector boxes and carried to a portable separator, which is placed over a manhole and returns the sand to the filter. After this is done, sand from the court or a bin is used to make up the required depth of 42 in. A special type of ejector, called a gun, is used to feed sand to the separator from the court or a bin. The separators remove the water from the sand, the sand passing into the filter by way of a chute and the water being discharged into the surface drain. To do this resanding, it takes one man to handle each gun and two men at the end of the chute in the filter. Generally two guns are used, requiring a total force of five men and a foreman. For each of the old filters, 2 940 cu. yd. of sand are required, and 4 620 cu. yd. for each of the new filters.

It is interesting to note from Table 2 that during 1927–1931 the average cost for handling a cubic yard of sand was $0.45 in scraping and $0.21 in resanding.

The maximum amount of water filtered on any one day was 24.46 m.g. on June 28, 1929, and the greatest amount filtered in any one year was 6 269.8 m.g. during 1929.

Million Gallons Filtered.

1927	—	5 413.34
1928	—	5 569.88
1929	—	6 269.80
1930	—	6 141.21
1931	—	5 950.72

The amount of water used in washing sand during the years 1915–1931 inclusive averaged 29 m.g. or 0.53 per cent. of the water filtered. The cost for operation and maintenance only per million gallons of water delivered to the city during 1911–1931 inclusive was $6.40; with interest on the cost of the plant this figure is increased to $11.22.

Analytical Results.

In the laboratory, daily tests are run for color, temperature, turbidity, alkalinity, and carbon dioxide; and pH readings are taken of the sedimentation basin influent, or river water, the basin effluent, and the mixed filtered effluent. The color is measured daily on the effluent from each filter; three times a week chloride determinations are made; dissolved-oxygen and iron content of the sedimentation-basin influent and filtered

effluent are determined twice a week, and total solids and volatile matter once a week.

It is interesting to compare the analytical results obtained during the twenty-two years that the plant has been in operation. The average

TABLE 3.—WATER USED IN SAND WASHING AND COST OF WATER FILTRATION.

Year.	FILTERED WATER USED IN WASHING SAND.		NET COST PER M.G. DELIVERED TO CITY.	
	Per cent.	m.g.	Operation and Maintenance only. $	Operation, Maintenance and Interest Charges. $
1931	0.70	41.6	7.09	16.84
1930	0.49	30.4	6.35	15.58
1929	0.56	35.7	5.47	14.42
1928	0.37	19.0	7.56	17.23
1927	0.37	20.1	7.20	17.17
1926	0.40	20.8	7.12	16.30
1925*	0.83	45.0	7.54	11.37
1924	0.55	29.2	7.68	11.51
1923	0.54	27.3	8.01	11.62
1922	0.57	26.7	8.15	11.21
1921	0.48	22.5	8.39	11.35
1920	0.53	25.7	6.44	9.35
1919	0.50	22.8	5.96	8.91
1918	0.38	18.7	4.73	7.45
1917	0.65	29.1	4.39	7.38
1916	0.50	20.8	4.40	7.57
1915	0.61	23.1	3.95	7.46
1914	....	....	4.38	7.71
1913	....	....	3.64	7.00
1912	....	....	3.57	6.92
1911	....	....	6.01	.....
Total	9.03	458.50	128.03	224.35
Average	0.53	29.0	6.40	11.22

*Four new filters added.

temperature of the river water has been 47.4°, and of the filtered water, 47.7°; the color of the river, 37.5 p.p.m., and of the filtered water, 17.6 p.p.m., a reduction of 53.06 per cent.; the turbidity of the river, 4.6 p.p.m., and of the filtered water, 0 p.p.m.; the alkalinity of the river, 7.5 p.p.m., and of the filtered water, 5.6 p.p.m.; the carbon dioxide of the river, 2.2 p.p.m., and of the filtered water, 3.1 p.p.m.; the chlorides of the river,

TABLE 4.—AVERAGE CHEMICAL ANALYSES

1910–

(With exception of Temperature and pH

Year.	Temperature.		Color.		Turbidity.		Alkalinity.		Hardness.		Carbon Dioxide.	
	R.*	F.†	R.	F.	R.	F.	R.	F.	R.	F.	R.	F.
1910	47.9	48.4	52.5	22.5	2.1	0	9.1	5.9	11.5	11.4	3.2	5.7
1911	41.9	42.2	50.0	18.6	15.4	0	12.2	8.3	10.8	11.8	4.3	7.4
1912	48.3	48.3	38.8	15.7	7.8	0	8.6	6.8	10.7	10.9	2.3	2.3
1913	45.0	49.4	41.9	16.5	7.8	0	8.4	6.5	13.5	14.5	1.6	2.7
1914	47.8	47.8	35.6	18.1	5.1	0	8.3	5.7	12.3	13.8	1.0	1.8
1915	48.0	48.3	41.8	18.6	7.8	0	9.3	6.9	12.7	12.8	1.4	2.4
1916	47.2	47.2	43.1	21.2	5.0	0	9.0	7.0	10.5	10.5	2.0	3.0
1917	47.0	48.0	35.0	18.0	1.4	0	8.0	6.0	9.7	9.8	2.3	2.8
1918	47.7	47.7	36.5	19.6	1.5	0	8.4	6.7	10.8	10.8	2.3	3.0
1919	48.5	47.6	36.3	18.7	1.7	0	6.5	4.8	9.0	9.0	2.0	2.8
1920	46.9	46.7	33.9	18.5	3.1	0	7.0	5.8	9.0	9.0	2.4	2.8
1921	48.8	49.6	34.11	17.3	3.3	0	7.0	4.7	9.0	10.0	2.5	3.0
1922	47.7	47.9	39.1	17.2	4.2	0	7.2	4.9	9.8	10.3	2.5	3.0
1923	47.5	47.7	34.7	18.0	1.8	0	6.5	5.0	9.0	10.0	2.2	2.8
1924	46.5	46.7	34.8	17.4	3.0	0	5.7	4.2	10.0	10.8	2.0	2.5
1925	48.3	48.1	32.1	19.0	3.5	0	6.3	5.0	10.3	10.1	2.0	2.5
1926	46.5	47.0	33.0	17.0	3.2	0	6.4	5.1	9.6	9.8	2.0	2.7
1927	48.0	48.0	39.0	17.0	3.3	0	5.6	3.7	9.2	9.9	2.0	3.0
1928	48.0	47.0	35.0	16.0	4.2	0	6.5	4.6	9.5	9.4	2.2	2.7
1929	49.0	48.0	29.7	15.0	5.0	0	5.2	4.3	9.2	9.3	2.0	2.9
1930	49.0	49.0	30.4	13.0	7.0	0	6.0	5.2	12.6	14.0	2.1	2.6
1931	48.0	49.0	38.6	13.8	4.5	0	7.8	5.0	13.0	13.5	2.0	3.0
Total	1 043.5	1 049.6	825.9	386.7	101.7	0	165.0	122.1	231.7	241.4	48.3	67.4
Average	47.4	47.7	37.5	17.6	4.6	0	7.5	5.6	10.5	11.0	2.2	3.1

*R river water.
†F filtered water.

FOR RIVER AND FILTERED WATERS.

–1931.

Determination Results are stated in p.p.m.

Chlorides.		Iron.		pH.		Dissolved Oxygen.		Solids.				Coagulant Used lb. per m.g.
								R.		F.		
R.	F.	R.	F.	R.	F.	R.	F.	Total.	Vol.	Total.	Vol.	
1.3	1.5	0.80	0.38	...	...	12.4	11.9	39.2	14.8	38.7	...	162.7
1.6	1.6	0.38	0.17	...	...	11.9	12.0	36.0	16.4	40.5	...	93.9
1.4	1.4	0.31	0.19	...	...	11.2	10.1	34.8	11.9	32.3	...	34.3
1.2	1.4	0.38	0.16	...	...	11.4	10.3	40.5	14.5	35.7	...	36.6
1.3	1.4	0.46	0.21	...	...	11.5	10.3	39.7	14.0	34.0	...	22.4
1.6	1.6	0.36	0.18	...	...	11.5	10.5	37.4	13.4	40.0	...	49.1
1.2	1.2	0.43	0.19	...	...	11.9	10.8	36.8	10.1	37.6	...	35.6
1.2	1.2	0.45	0.19	...	...	11.7	11.2	39.8	16.1	38.0	...	35.4
1.6	1.7	0.37	0.16	...	...	11.9	11.0	39.0	21.4	37.3	...	30.3
1.5	1.6	0.32	0.12	...	...	12.1	11.1	36.8	13.6	36.0	...	40.2
1.4	1.6	0.27	0.13	...	...	12.1	11.3	40.1	17.0	33.0	...	37.2
1.2	1.2	0.33	0.14	...	...	11.7	10.9	36.6	16.5	37.0	...	43.5
1.3	1.3	0.27	0.11	...	...	11.2	11.1	39.6	17.0	36.4	14.0	59.3
1.1	1.1	0.26	0.13	...	...	11.9	10.9	39.0	17.0	35.0	14.0	33.9
1.1	1.1	0.35	0.12	...	...	11.4	10.6	39.7	20.6	31.7	15.6	37.2
1.1	1.1	0.25	0.11	6.5	6.3	11.7	10.8	42.6	20.3	30.2	15.8	32.6
1.2	1.2	0.27	0.11	6.7	6.5	11.9	10.9	42.3	21.3	35.0	17.0	31.6
1.1	1.1	0.20	0.08	6.5	6.3	11.5	10.9	38.0	18.0	35.2	13.4	43.8
1.1	1.2	0.21	0.08	6.8	6.4	12.0	11.0	38.8	15.3	34.5	12.6	34.7
1.1	1.1	0.29	0.09	6.8	6.5	11.7	10.9	37.4	13.6	34.5	10.8	23.8
1.2	1.2	0.38	0.09	6.9	6.5	11.7	10.7	45.4	13.9	33.8	9.6	44.2
1.2	1.1	0.28	0.09	7.0	6.5	11.7	10.8	44.2	15.5	37.0	9.5	56.8
28.0	28.9	7.62	3.23	447.2	45.0	258.0	240.0	863.7	352.2	783.4	132.3	1 019.1
1.3	1.3	.35	.15	6.7	6.4	11.7	10.9	39.1	16.0	35.6	13.2	46.3

TABLE 5.— AVERAGE BACTERIAL COUNTS AND PRESUMPTIVE TESTS FOR B. COLI IN RIVER AND FILTERED WATERS. 1910–1931.

Year.	20°C. Count.		37°C. Count.		No. Tests.	River Positive.	Filtered Water Positive.
	River.	Filtered-Water.	River.	Filtered-Water.			
1910	673	25	....	....	165	30	2
1911	530	58	....	....	215	51	..
1912	549	19	....	....	312	28	..
1913	518	13	....	....	299	74	..
1914	411	11	....	....	305	80	..
1915	511	15	....	....	309	76	..
1916	442	10	32.0	0.17	305	57	..
1917	393	17	2.0	0.0	314	27	..
1918	468	13	5.4	0.53	306	55	..
1919	337	13	9.4	0.80	309	40	..
1920	439	15	13.3	1.20	313	44	..
1921	366	21	12.6	0.92	313	23	..
1922	371	13	15.0	0.76	312	44	..
1923	262	12	10.0	0.40	312	26	..
1924	297	12	18.0	0.95	314	46	..
1925	352	12	12.0	0.37	315	39	..
1926	218	9	6.4	0.10	314	31	..
1927	286	9	10.0	0.26	313	79	..
1928	269	7	13.0	0.36	312	56	..
1929	231	9	11.0	0.42	312	36	..
1930	177	3	12.0	0.50	313	69	..
1931	201	5	14.0	0.50	311	78	..
Total	8 301	321	196.1	8.24	6 593	1 089	2
Average	377.3	14.6	12.3	0.52	299.7	49.5	..
Per cent. Reduction	96.13		95.77				

1.3 p.p.m., and of the filtered water, 1.3 p.p.m.; the iron of the river, 0.35 p.p.m.; and of the filtered water, 0.15 p.p.m.; the dissolved oxygen of the river, 11.7 p.p.m., and of the filtered water, 10.9 p.p.m.

The bacteriological work at the plant consists of making daily the 20°C. gelatine count on the river water, sedimentation basin effluent, the effluents from each of the ten filters, from the two wet wells into which these filters empty, and from the filtered effluent as it goes to the city. The 37°C. count on litmus-lactose agar, and the presumptive test for *B. coli* is made daily on the river water, sedimentation basin effluent, and

the filtered water as it goes to the city. The average 20°C. count for the twenty-two years has been 377.3 for the river, and 14.6 for the filtered water, making a reduction of 96.13 per cent. For the 37°C. count, the average for the river has been 12.3, and for the filtered water, 0.52, a reduction of 95.77 per cent. Of the 1-cc. presumptive tests for *B. coli* 49.5 out of the average per year of 299.7 gave a positive reaction, showing that *B. coli* was present in only 16.52 per cent. of the 1-cc. river-water samples. In the twenty-two years of operation, the filtered water has always given a negative test, indicating that *B. coli* was never present in 1 cc. of the filtered water.

Chemical Treatment.

Commercial aluminum sulphate is used for the coagulation of color in the raw water, and lime is added when there is not enough alkalinity in the water to take care of the alum used. Daily tests are made in the laboratory for the required amount of coagulant to be added to the water. It is customary at this plant to treat the water only when it has a color above 25 p.p.m., which is the color desired for water going to the filters. Owing to the large sedimentation-basin capacity we have adopted what we call an "overdose method" of treating the water; that is, giving the treatment in half the time required. As the alum is fed at the control house before the water enters the basin, the extra coagulant reacts with the water already in the basin and keeps on reacting with the incoming water after the alum feed has been shut off. An example will illustrate our method. With a filtration rate of 24 m.g.d. and a color of 50 p.p.m. in the water and an alkalinity of 10 p.p.m., the amount of coagulant necessary to reduce the color to 0 p.p.m. being 150 lb. per m.g., it would take 1 800 lb. of alum to decrease the color of this volume of water from 50 to 25. Our method is to cut the time of this application from 12 to 6 hours by doubling the amount of coagulant. The result obtained is a larger floc and better settling in the sedimentation basin. Coagulant is added about one-quarter of the time. Sometimes the dosing period has been as low as two hours while at other times it has been higher than eight hours.

It has been my personal observation that filtered water with a color of 15 p.p.m. as a result of chemical treatment is better in appearance than filtered water of the same color which has not been treated. As shown in Table 4, the average amount of coagulant used during the 22 years of operation has been 46.3 lb. per m.g., equalling 0.324 grain per gal. For every point of color reduction per million gallons 2.33 lb. of alum were used.

It should be mentioned that to keep the pollution of the water at a minimum, trucks are used to carry away the night soil from the watershed.

The successful operation of any filtration plant depends upon the coöperation of all concerned with it, from the chief engineer to the laborers. Springfield is to be congratulated upon its unusually capable and efficient engineer and the fine type of men who have been its mayors and water commissioners.

HYDRO-ELECTRIC POWER DEVELOPMENT AT COBBLE MOUNTAIN, IN CONNECTION WITH THE SPRINGFIELD WATER SUPPLY.

BY HERBERT A. MOODY.*

[*Read September 27, 1933.*]

The interesting features in connection with the development of hydro-electric power at Cobble Mountain are:

I. The Agreement Between the City of Springfield and the Turners Falls Power & Electric Company.
II. The Large Capacity of the Power Development.
III. The Unusual Physical Features of the Power Development.

Agreement Between the City of Springfield and the Turners Falls Power & Electric Company.

This agreement makes possible the distribution, in Western Massachusetts, of power from the potential energy in the water stored in Cobble Mountain Reservoir.

It will be of assistance in following the terms of this agreement to refer to the map accompanying Mr. Lochridge's paper in this issue of the Journal. This map shows the relative location of reservoirs mentioned, together with a profile showing relative elevations.

Briefly, the agreement between Springfield and the Turners Falls Power and Electric Company gives the company under a thirty year lease, all the power it can generate at the power plant from a storage capacity in Cobble Mountain and Borden Brook reservoirs amounting to a maximum of 2.9 billion cubic feet. The gross head from the flashboard crest of Cobble Mountain reservoir to the minimum tail water at the power plant is 460 ft. From this storage capacity the power company must pass through the power plant sufficient water for daily city consumption, and cannot use amounts in excess of this to draw Cobble Mountain reservoir below certain elevations stipulated for the first of each month. The maximum capacity of 2.9 billion cubic feet is that above the minimum elevation of draw which is stipulated for the first of March. In Borden Brook and Cobble Mountain reservoirs there is additional capacity of about 400 million cubic feet, or 3 billion gallons, which may be drawn by opening the gates of the diversion tunnel at the Cobble Mountain dam, these being at an elevation about 76 ft. lower than the power-tunnel gate. This provides a reserve to insure the city against a protracted dry season beyond March first.

When the average use by the city for any calendar year exceeds 20

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m.g.d., the stipulated elevations limiting the draw of Cobble Mountain reservoir are raised, with further increases for each succeeding 5 m.g.d. average use by the city for any calendar year. This provision, while necessary to the city for increasing its reserve with its growth in demand, decreases the storage capacity allowed the power company and consequently reduces the value of the lease to that company. It is therefore provided that when the average use by the city for any calendar year exceeds 30 m.g.d., there shall be a decrease in the annual rental paid by the power company, and further reductions shall be made with each successive increase of 5 m.g.d. average use for any calendar year.

The power plant is located so that its wheels discharge directly into the intake reservoir, its minimum tail water elevation being 8 ft. below the top of the proposed four-foot flashboards on the Intake Dam. Whenever chemical treatment of the water is not required, the power company may, if it so desires, pass water through the plant in such a manner that the daily city demand lowers the elevation of the intake reservoir 20 ft. below the flashboard crest, provided that once each day, except Sundays and holidays, it is raised to an elevation 6 ft. below the flashboard crest. To lower the intake reservoir 20 ft. requires drawing for city use 43.3 m.g. from the intake reservoir and 27.64 m.g. from the sedimentation basin at the filters into which the water from the intake reservoir discharges. This provision enables the power company to use the city water to best advantage when treatment is not required, that is, for carrying its week-day peaks, and passing no water from Saturday noon until Monday morning.

When chemical treatment is required, the power company must on no day permit the water of the intake reservoir to be lower than 8 ft. below the flashboard crest, and for 20 hours each day not lower than 6 ft. below that crest. These 8 feet have a capacity of 20.6 m.g. while the 6 feet have a capacity of 15.8 m.g.

Large Capacity of the Power Development.

The capacity of the equipment in the power plant is 23 000 k.w. when operating at the minimum effective head of 330 ft. At maximum effective head the capacity is 33 000 k.w. With the station operating to capacity it is expected that the maximum effective head at the wheels will be about 420 ft. The difference of 40 ft. between the gross head of 460 ft. and the effective head of 420 ft. being velocity and friction head losses together with the loss in draft head due to the higher tail water below the station because of maximum wheel discharge.

The wheel discharge under this condition of maximum capacity operation will be 1 100 c.f.s., or 24.2 c.f.s. per square mile for the 45.5 sq. miles of drainage area above Cobble Mountain Dam. The average run-off from the drainage area of 48.5 sq. miles above the intake reservoir for the 26 years, 1906 to 1931 inclusive, was 61.49 m.g.d., or 94.8 c.f.s., or 1.96 c.f.s.

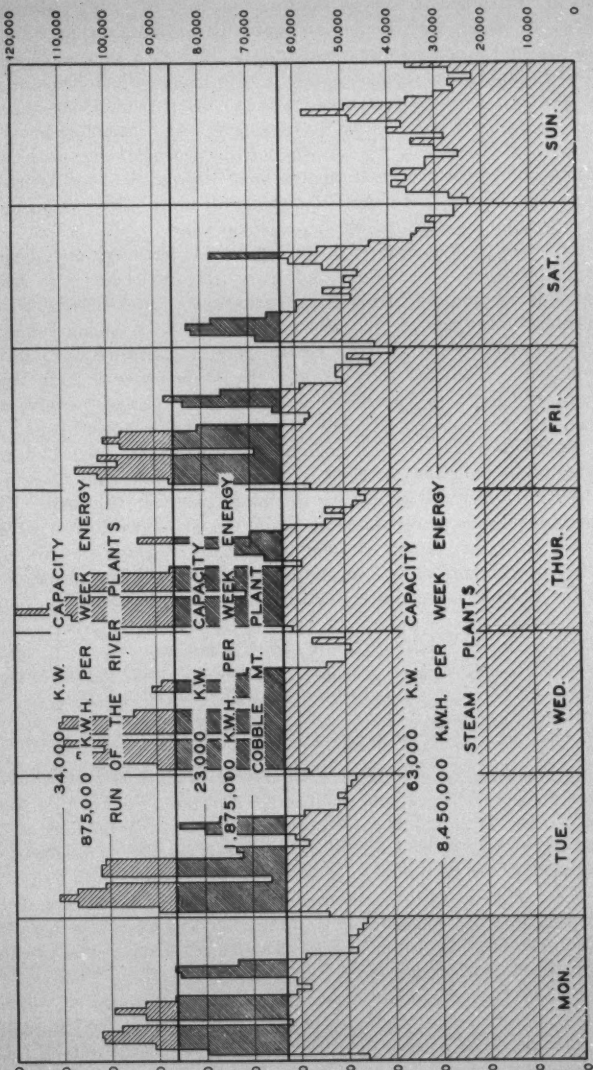

FIG. 1. — AVERAGE WEEKLY LOAD CURVE OF THE WESTERN MASSACHUSETTS COMPANIES' SYSTEM.

per square mile. This developed capacity requiring 24.2 c.f.s. per square mile of drainage area is an example of the practice, which is being adopted to a growing extent, of utilizing such plants, drawing directly from some considerable storage to operate with other hydro-plants in a power system, which are generally classified as "run of the river" plants, and with this

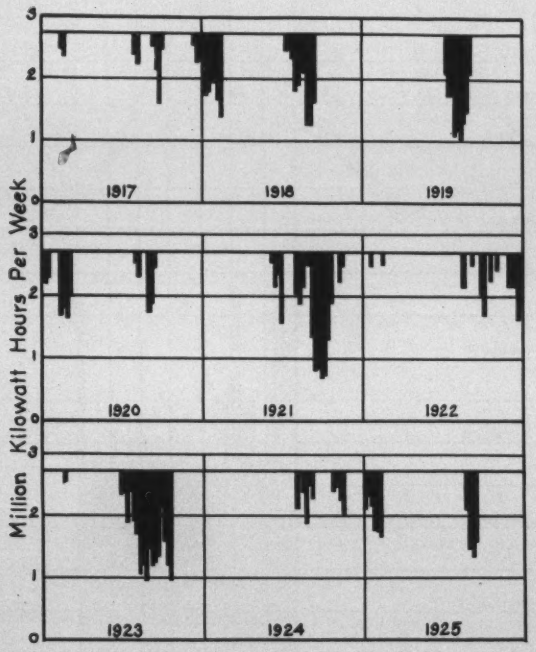

FIG. 2. — WEEKLY OUTPUT REQUIRED OF COBBLE MOUNTAIN RESERVOIR TO CARRY WITH THE RUN OF THE RIVER PLANTS THE TOP 57 000-KW. LOAD, OF THE WESTERN MASSACHUSETTS COMPANIES' SYSTEM.

combination to carry the power peak through the low river-flow season of the year.

To illustrate how this large capacity is utilized to its maximum extent by the power company, consider the load curve shown by Figure 1, which is the expected average weekly load curve of the Western Massachusetts Companies' system (of which the Turners Falls Power & Electric Co. is a part), at the time when the power peak reaches 120 000 k.w. The record week of minimum river flow would produce at the "run of the river" plants

875 000 k.w.h. per week. During such a week these plants would operate on the extreme top of the load curve as shown in order to utilize the greatest possible amount of their installed capacity. The maximum capacity obtainable from these plants would be 34 000 k.w. The 63 000 k.w. of

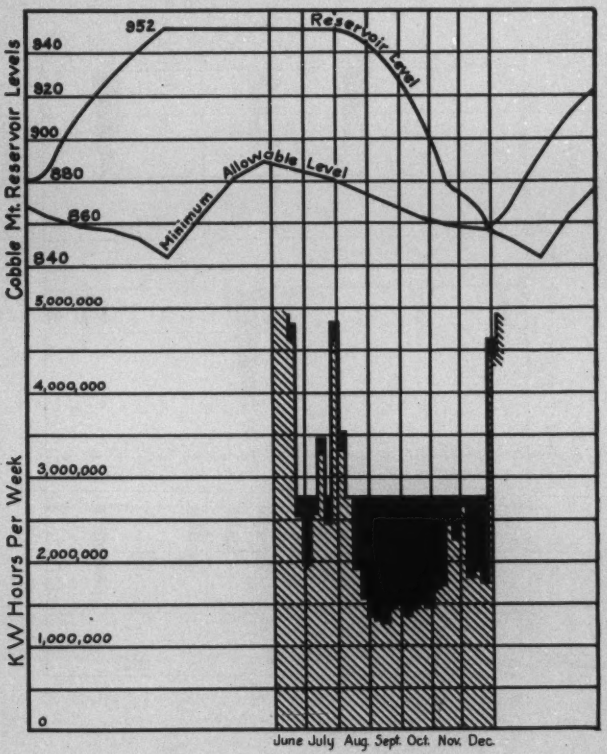

FIG. 3. — OPERATION OF THE COBBLE MOUNTAIN PLANT DURING A DRY YEAR. SOLID AREA: COBBLE MOUNTAIN OUTPUT. CROSS-HATCHED AREA: TURNERS FALLS AND GARDNERS FALLS OUTPUT.

steam capacity during such a week of minimum river flow would carry the base of the load as shown, and the balance of 23 000 k.w. of capacity would be obtainable from the Cobble Mountain station, even should this minimum river-flow week occur when the reservoir is at its extreme low level with but 330 ft. effective head at the wheels. Figure 1 illustrates the week

when the maximum of draw from Cobble Mountain reservoir will occur with such a load curve. For this condition it will be necessary to furnish 1 875 000 k.w.h. per week from the Cobble Mountain station. As the river flow at the "run of the river" plants increases, the demand on the Cobble Mountain plant will decrease until such river flow is sufficient to produce 2 750 000 k.w.h. per week, when no water will be drawn from Cobble Mountain reservoir except that necessary to furnish the city its daily supply. The power from this daily water which at a rate of 20 m.g.d. will average about 145 000 k.w.h. per week, will of course be used to save 145 000 k.w.h. of the steam shown on the bottom of the load curve.

Figure 2 shows by the sectioned areas, through a period of years, 1917 to 1925 inclusive, the occasions when, and amounts by which, the recorded river flow at the "run of the river" plants would have failed to produce 2 750 000 k.w.h. per week, and these sectioned areas also measure the number of kilowatt hours which would have been demanded from the Cobble Mountain station. Evidently the year 1923 was the year of greatest demand for the period shown, and though the records much further back than 1917 were investigated, only 1908 would have caused an equal demand.

Figure 3 shows in larger scale the year 1923, the shaded area indicating the amount by which the "run of the river" plants would be deficient and the kilowatt hours demand on Cobble Mountain station. The upper portion of the figure shows the drop in reservoir level due to such a demand, completely exhausting the capacity above the limitation level specified for January 1 at 20 m.g.d. city use.

This station then, will save the power company the annual cost of 23 000 k.w. of firm capacity together with the coal cost of producing by steam 20 million k.w.h. per year, which is approximately the output which can be obtained from the average annual run-off of the drainage area above Cobble Mountain Dam.

Unusual Physical Features of the Power Development.

Among the somewhat unusual physical features of this development may be mentioned the differential surge tank which is of the contracted orifice type, instead of the more common type which employs a central riser. Also the customary frost cover is omitted on this surge tank. A small air compressor located in the adjacent gatehouse, and on thermostatic control, operates with temperatures below freezing to discharge air from small holes in a circular pipe attached to the bottom of the tank. This air rising to the surface of the water in the tank, causes water currents within the tank to mix the water of higher temperature coming through the tunnel from the reservoir with the colder water at the sides and top of the tank and maintains the entire body of water within the tank at a more or less uniform temperature somewhat above freezing.

The conduit from the tunnel, after passing the surge tank, connects to a manifold which feeds three steel penstocks, each about 600 ft. long. The tunnel conduit is but an extension of the steel tunnel-lining, which extends into the tunnel about 440 ft. The longitudinal joints of this conduit and of the three penstocks are welded by the electric arc process. The penstock sections were fabricated in the shop in 30-ft. lengths and each subjected

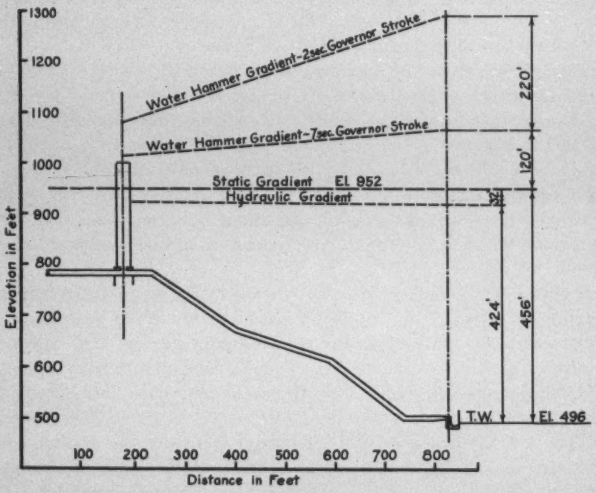

FIG. 4. — DIFFERENCE IN PENSTOCK PRESSURE DUE TO SEVEN-SECOND GOVERNOR MOVEMENT AND TWO-SECOND GOVERNOR MOVEMENT.

before delivery to a hydraulic pressure 50 per cent. in excess of the maximum that it would be subjected to under operating conditions. After erection each penstock line was tested for leakage with hydraulic pressure 10 per cent. in excess of maximum operating pressure. In the design of these penstocks, economy required holding the water-hammer pressure as low as possible. This was accomplished by adopting a governor movement which closes the turbine gates from wide open position in seven seconds with full load thrown off. This slow governor movement is quite an unusual feature. Figure 4 is a diagram which illustrates the difference in penstock pressure at this plant between operation with a seven-second governor movement and a two-second governor movement. The slow governor movement results in an overspeed of the units occurring at times of loss of full load amounting to 85 per cent. in the case of the small unit and 67 per cent. for the two large units, thus making necessary a relay switch to automatically

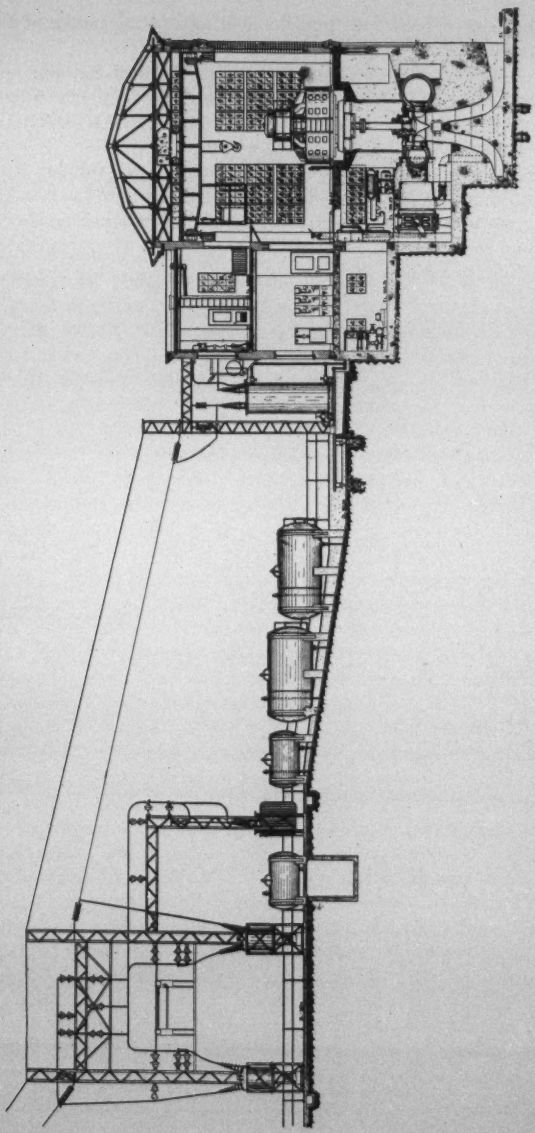

FIG. 5. — CROSS-SECTION OF COBBLE MOUNTAIN POWER STATION.

cut off the excitation current from the field coils of the generator at times of such speed rise.

Fig. 5 shows a cross section of the station which contains one unit of 5 760 kva capacity for use when passing only the daily city supply and two units of 13 620 kva capacity for use when relaying the "run of the river" plants.

Current from each generator at 6 900 volts passes through its transformer and circuit breaker to the 69 000 volt bus and onto the two outgoing lines, a circuit breaker being provided for each line. There is no low-tension bus, station service being provided by three 150 kva transformers tied to the high-tension bus with fuses.

POWDERED ACTIVATED CARBON IN WATER PURIFICATION.

DISCUSSION OF PAPER BY F. E. STUART.

This JOURNAL Vol. 46 No. 3 September, 1932, p. 312.

M. C. SMITH.* Powdered activated carbon has become a necessity at the Richmond plant, and, probably in so many others that its most efficient and economical use is a matter of much importance.

Mr. Stuart has added new and interesting reasons for the use of activated carbon and experiments conducted by the writer, in general, confirm Mr. Stuart's opinions.

However, he states: "...it (carbon) remains in contact with the water for very long periods of time before it settles out. It is while in suspension that the carbon gets in its most effective work." For taste and odor removal, the writer's experiments, both in the laboratory and in plant operation, prove conclusively that filtration through the carbon is considerably more effective than suspension of the carbon in the water.

He also says: "In the early use of powdered carbon it was applied directly to the water entering the filters. This practice is being continued at several plants. . . ." In the Richmond plant, carbon was first applied to the raw water about ten minutes before the coagulant,—sulphate of alumina. This was found to require about ten times as much carbon for taste and odor removal as was needed when the carbon was fed into the coagulated water immediately before filtration.

Most of the benefits which have been pointed out by Mr. Stuart were confirmed in varying degrees by our experiments. It is evident that the point of application becomes a matter of economy. On the one hand, we feel certain that application immediately before filtration is most efficient in taste and odor removal from the standpoint of the quantity of carbon required. Against this gain must be balanced the loss incurred by reduced filter runs, the objection of less stable deposits in the settling basins, and the relinquishing of other benefits which Mr. Stuart has mentioned as possible when carbon is applied before coagulation. The reduction of filter runs will probably be the most important disadvantage, particularly during seasons when runs are unduly short even without the use of carbon.

The carbon feed at the Richmond plant is so arranged that the point of application may be changed by the operation of two small valves. However, since the economy and efficiency of carbon application just

*Engineer of Water & Electricity, Richmond, Va.

before filtration has been established, it has at no time been found advisable to shift the point of application ahead of coagulation.

In conclusion, the writer is in full agreement with Mr. Stuart when he says: "...the preferable arrangement should be determined by tests," and is of the opinion that arrangements should be made in the plant to permit application of the carbon at either or both points, before coagulation or just before filtration.

L. H. ENSLOW.* At Richmond, Virginia, Mr. Smith has done an excellent job with prechlorination and activated carbon in combination. As he says, he finds it is preferable to apply the carbon just ahead of the filters. I might amplify this statement by explaining that Mr. Smith has created considerable improvement in the operation of his coagulating basin. In view of that, none of the carbon that he would add to the raw water, or practically none, would reach the filter. It does seem that when carbon is applied to the raw water, enough will remain in suspension to be deposited on the filter bed, but results are unreliable in comparison with those obtained by applying at least a part of the carbon just ahead of the filters, so that it cannot escape being deposited on top of the sand and work a little into the filter bed. I think that is an important aspect of the situation. If settling-basin detention-periods are long, undoubtedly the place to apply carbon is just ahead of the filters. On the other hand, there are benefits to be obtained from splitting the treatment; some carbon being added to the raw water and some to the applied water.

When it comes to the final analysis of the situation, every man must study his own plant and determine at what point the carbon, like chlorine, is most effective under the existing conditions.

The use of activated carbon has shown it to be phenomenal in its ability to produce an excellent grade of almost spring-like water where heretofore the water may have been objectionable and given rise to complaints.

M. M. GIBBONS.† At Rahway, N. J. powdered activated carbon has removed odors and tastes due to industrial wastes. As has been pointed out, that portion of the carbon which is carried onto the filter bed should be most effective in creating good absorption of the taste-producing constituents. For that reason we wanted to apply the carbon directly to the filter except when we used large doses, which would shorten filter runs. By compromise we applied the carbon midway between the two coagulation basins, or at the entrance to the second basin. With application at that point the carbon is carried onto the filter beds, and we get good removal of taste-producing substances. Powdered activated carbon is rather expensive when pollution is severe, but as opposed to the complaints we get from bad-tasting water we have found the expense has been worth while. Using it in combination with prechlorination we spend about $5

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†Chemist, Water Purification Works, Rahway, N. J.

per million gallons. The water commissioners have thought it paid to spend the money because it has cut down the complaint calls. Where there is chronic pollution by industrial wastes it is essential to use some sort of treatment material like activated carbon that will keep the water palatable at all times.

CHARLES R. COX.* I have been requested to outline briefly the success of this treatment in New York State. There are only about five plants that are using activated carbon, and one of them—at Hamburg—followed the work at New Milford of the Hackensack Water Company, in the successful use of powdered activated carbon applied to the water flowing to the bed rather than the raw water.

We have found out that it is essential that the carbon be maintained in contact with the water for appreciable periods of time and preferably for some time on the beds. Therefore, if there are no effective mixing basins in which to stir the raw water, it is wasting carbon to apply it to the raw water because most of it will settle very quickly in the first portion of the coagulation basin. When that is the case, most of the carbon should be applied to the water flowing to the filters. If this arrangement threatens the filter runs, the only alternative is to install mixing equipment, using baffles or some other form of mixer.

From the standpoint of the consumer the success attained by using activated carbon has been very great, and it has placed in the hands of the water-works operator a tool which will enable him to turn out a water that is attractive, as contrasted to many of the waters delivered at the present time.

The value of activated carbon in adsorbing soluble materials is not emphasized to a sufficient extent, it appears to me, because many of the tastes in water which consumers complain of—not so much in the form of telephone calls but by remarking that they do not like the water of a certain city and do like the water of another city—are frequently a matter of the organic content. In other words, if the organic matter is low, people will say that the water is like spring water; if it is high, they will say they do not like the water because it is musty. A water-works superintendent may have a safe water but that water may have a high organic content which is disagreeable. Naturally he is not pleasing his customers as much as he would if it was removed. Therefore, carbon in two ways, by improving coagulation and by actual adsorption, enables the operator to turn out a water which is better in taste even though he is not faced with serious taste problems.

We have several instances in our state where phenol tastes are troublesome. Ammonia treatment and use of activated carbon, not necessarily used together, are contributions to water-purification practice in the last few years which constitute a tremendous step forward in enabling the profession to turn out water which is both safe and attractive.

*N. Y. State Department of Health, Albany, N. Y.

JAMES E. KERSLAKE.* At Ossining, N. Y. we are adding carbon with the alum, just ahead of the mixing tank. We have been able to save from 40 to 80 lb. of alum in treating water that has a color of 50 to 90 p.p.m. Our carbon dose has run between 12 and 20 lb. When we can get along with 12 lb. of carbon we save often as much as 50 per cent. on our chemical costs. When we use 20 lb. of carbon at 8c per lb. and save 40 lb. of alum at 4c per lb. we break even. Since using carbon we have had practically no trouble with pin-point floc in winter and after the carbon works into the filters we get much better results than are apparent when carbon is first used.

R. G. YAXLEY.† Our plant is situated on the upper reaches of the Hudson River. The water contains much decayed vegetation from swampy upper reaches, and at certain busy seasons of the year is highly polluted with sulphite wastes from paper mills. Ammonia-chlorine treatment has been tried with no appreciable benefit, and prechlorination has been tried, until we had an excess of chlorine going through the filters so that it could be tasted. During the summer we are able to take care of things nicely by means of a spray-nozzle aërator. If one stands on the lee side of that aërator one appreciates the fact that it is doing business. In cold weather, when it becomes impossible to operate the aërator, the trouble begins. For two years we have experimented with activated carbon. It is a wonderful help. But we do not manage to use only 1 or 2 lb. per million gallons, nor do we find any improvement in coagulation. Mr. Kerslake mentioned the fact that he experiences difficulty with pin-point floc in the winter. I think that if coagulation is properly carried out pin-point floc will be avoided. That is so in our plant, after thorough mixing. Hence I cannot say that carbon improves coagulation.

In regard to tastes and odors, however, carbon is the only chemical we have been able to find that will assist in the solution of our problem. Anyone who has had experience with carbon knows that it is a material which sticks to whatever it comes into contact with. What will this do to the filter eventually?

MR. STUART. Last week I had the opportunity of stopping at Toledo, O., where they have been using carbon for seventeen months. The filters have been subject to mud-ball formation, and the filter runs have been as low as seven hours at some seasons of the year. The operators claim that since using carbon the filters wash better and break loose easier. That would mean that the carbon, instead of being sticky, when mixed with sand, gives the same result as when it is mixed with sugar of iron. Iron sulphate, by itself very sticky, is handled readily when carbon is added. At Norfolk carbon has been used for 15 months. Microscopical studies of the sand showed that carbon had penetrated 8 inches into the filter but no farther.

*Chemist with N. S. Hill, New York, N. Y.
†Superintendent, Waterford, N. Y.

MR. GIBBONS. We have used carbon for about eighteen months, sometimes in large doses, up to 20 p.p.m. So far the carbon has not caused us much difficulty in the sand, but we feel that the sand will eventually have to be washed. We have made some preliminary tests with a sand washer, using sand containing carbon, and we find that the ordinary hydraulic sand washer will remove a great proportion of that carbon. Hence we feel that we can solve the problem by washing. With wash water velocities up to 24 inches vertical rise per minute we have not been able to keep the sand free from carbon. It has penetrated practically into the sand to a depth of about 24 inches.

ROBERT SPURR WESTON.* I would like to say just a word about the use of activated carbon as an aid to coagulation. I had to do last summer in eastern Pennsylvania with a filter plant having a capacity of 12 to 14 m.g.d. We found that the addition of 4 pounds per million gallons of activated carbon was a great aid in removing the odors and tastes, and that it also had a beneficial effect upon coagulation. In this case the water was highly colored and very clear, and the addition of carbon started coagulation just as the addition of clay would.

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THE INCH–FOOT METHOD OF CHARGING FOR PUBLIC FIRE PROTECTION SERVICE.

BY FRANK J. GIFFORD.*

[*Received †November 12, 1932.*]

The two chief functions of the water-supply system of the Dedham Water Company are:

(1) The giving of public fire-protection service; and
(2) Domestic and industrial service.

The latter includes private fire-protection and miscellaneous town service.

The public fire-protection service is almost entirely a "stand ready to serve" service, as the consumption of water for this purpose is practically negligible, hence the costs of this service are generally taken to be entirely capacity costs.

The present fire-protection rates of Dedham were established, in common with all other works built about the same time, on what might be termed "the average nearby rate," or the requirement that hydrant rental and water rates should not exceed the water rates paid in the surrounding district or state; or based upon the amount of income necessary to meet investment in plant, rather than any equitable consideration of the cost or value of the service rendered.

Gradually, the basis of charge has tended toward the *cost* of the service. In very few cases has it gone materially beyond this in the direction of the *value* of the service. To determine this cost we must first determine the total amount necessary to meet operating and maintenance charges, taxes, depreciation, and a fair return upon the capital investment. It is then necessary to apportion the source of this income to the two chief functions previously named.

It would not be fair to place this entire burden upon the town as a fire-protection rate, and it is equally unfair to absorb the fire-protection charge in the domestic and industrial rates.

If the fire-protection rate was absorbed in this manner it would discriminate against the resident water consumer in favor of the non-resident taxpayer and the owner of vacant property in meeting the town's just expenses for fire protection.

Experience has shown, and the National Board of Fire Underwriters has determined, that the cost of that portion of the water works involved in fire-protection service in a town the size of Dedham generally constitutes about 60 per cent. of the entire cost of the physical property. This fact is also recognized by the courts and public utility commissions generally. The

*Treasurer, Dedham Water Company, Dedham, Mass.

†Prepared March 1928.

Wisconsin commission stated that its analyses showed that in the average plant from 50 per cent. to 70 per cent. of the plant was assignable to fire-protection service, and fixed the rate on plant division, even though the pressure was low.—*In re* Shoreham, P. U. R. 1925—B, 43.

If rates for public fire-protection were fixed upon the basis of actual cost, the rates for domestic service and industrial service would be reduced accordingly.

We now come to the methods of charging for public fire-protection service.

Three general methods of determining the annual charges for fire-protection service are in use, based upon:—

1. Hydrant rental.
2. Charge per mile-of-pipe (4 inches or larger in diameter) with an allowance per hydrant for maintenance.
3. Charge per inch-foot of pipe distribution system (4 inches and larger in diameter), with allowance per hydrant for maintenance.

Annual Hydrant Rentals. This first and oldest method, and the one most generally used, is the least desirable, because there is nothing in principle to justify this basis of charge. It is illogical and improper for the following reasons:

1. It does not apply the payments to what the public really pays for, *viz.*—pumping capacity, distribution capacity, and the number of hydrants.
2. It has a tendency to contract the fire-fighting efficiency, by concentrating the payments on an outlet fixture, thus constantly tempting the town to improper economy by neglecting to install the proper number and to provide close spacing of the hydrants, with increasing fire risk in any given district.
3. It spreads the cost of fire protection inequitably, in that the town has to pay for outlying districts, with low fire-protection risks, as much per hydrant as in central business property with high protection risks.
4. It discourages the extension of the distribution system into outlying districts, by reason of the relatively high cost of the hydrants needed.
5. It does not encourage the use of adequately sized mains, because attention is concentrated on the hydrant and its spacing, rather than the size and capacity of the distribution system.
6. It discourages the setting of additional and intermediate hydrants when the adjacent fire risks increase, even though capacity of mains may be available.

The Charge per Mile of Pipe, with Annual Allowance per Hydrant for Maintenance. This method has good ground in principle for its use and is a distinctly better basis of charge than hydrant rental. It has the merit that the annual charge for fire-protection service increases with the increase of pipe laid and with the number of hydrants.

The criticism of this method is that payment is for length of pipe only, size or capacity not being considered.

The Charge per Inch-foot of Pipe Distribution System with Annual Allowance per Hydrant for Maintenance. This method is generally considered the most equitable of the methods yet devised. It is founded upon

sound principle, is easy of application and increases the rate equitably with the extension of the service. By this method an annual charge is made in cents, or in fractions of a cent, per inch-foot of pipe, and a charge per hydrant for maintenance.

The number of "inch-foot" units is obtained by multiplying the linear feet of pipe of each diameter by the diameter in inches. Thus a pipe line 12 inches in diameter, 50 feet long, is said to contain 600 inch-foot units. The annual charge per hydrant for maintenance is based upon the average annual cost of operating, maintaining and repairing the hydrants, and of providing allowance for taxes, depreciation and reasonable return upon the investment in them.

The whole basis of the inch-foot charge rests on the theory that the main element of fire protection is a readiness to serve, and not the quantity of water used. The cost of maintaining a plant large enough to produce a sufficient quantity of water to meet the sudden emergency of fire is the cost of the fire-protection service, and the rate should be sufficient to cover this. Since such cost corresponds roughly to the size and length of the mains, a rate based on the inch-diameter foot-length of main large enough for fire protection (that is, 4-inch and larger) is a fair measure of a fire-protection service.

It makes little difference whether the hydrants are attached to all the mains or not, or whether any water is actually drawn from all the hydrants which are attached, so long as the mains are a necessary part of the system for rendering the service.

The advantages to the town of this arrangement—the inch-foot basis—are:

1. The town proportions its payment to the amount of distribution pipe capacity it receives, as well as the number of hydrants that are available.
2. There is every incentive to the company, in extending its distribution system, to keep sizes of mains up to the fire requirements, and to reinforce weak districts. The town's interest in fire protection and the company's interest in proper remuneration are thus coördinate.
3. There is no obstacle to the introduction of new hydrants when given districts need increased fire protection, and thus the fire department is rendered much more efficient.

The town would be the direct beneficiary of an increase in the number of hydrants, for the greater number of hydrants, the closer they would be together, and the less the amount of hose and other equipment the fire department would be obliged to carry. The value to the town of this reduction in hose will far exceed the cost of furnishing additional fire hydrants. The shorter the hose length, moreover, the more effective the fire stream.

AËRATION IN WATER TREATMENT.

BY HERMAN ANDERSON.*

[*Read September 28, 1932.*]

The term, "Aëration," is ordinarily used in connection with mechanical devices or processes especially intended to increase the surface or interfacial contact between water and air to be mixed. Nearly every waterworks man is familiar with aëration and the benefits to be gained by removing tastes and odors resulting from the cycle of growth and decay of algæ or plankton; but during the past two years, particularly, much attention has been directed toward the increase in coagulating efficiency when aëration can be combined with concurrent mixing of coagulants.

Purpose of Aëration.

Heretofore four primary reasons have been assigned for the use of aëration; (1) the removal or sweeping out of objectionable, volatile odors of organic origin; (2) the removal or reduction of carbon dioxide and hydrogen sulphide gases; (3) the oxidation of ferrous iron and manganese; (4) the restoration of dissolved oxygen content.

A fifth and major reason for combining aëration with the simultaneous mixing of coagulant will be presented subsequently.

Aëration is probably considered first of all in connection with tastes and odors associated with both plant and animal life inhabiting the water or the surrounding soil with which the water has been in contact. These unpleasant tastes and odors which may be present periodically in impounded supplies yield readily to removal by aëration. Many forms of algæ during growth and subsequent decay exude essential oils, which impart to the water disagreeable tastes and odors. For the most part oily substances and dissolved gases are volatile; because they are volatile they can be driven off by what Whipple terms a "sweeping out" process with fresh air. It is needless to say that the greater the area of interfacial contact between fresh air and water the greater will be the rate of exchange — or effectiveness of aëration.

Aëration for the removal of carbon dioxide is valuable in treating ground water or well supplies. It is commonly used to remove or reduce the concentration of this gas which renders the water aggressive to iron, or steel, pipe and to the distribution system in general. Well waters sometimes contain iron in solution. By aëration the iron can be oxidized from the soluble ferrous form to the insoluble ferric form. When the iron is thrown out of solution it is subject to flocculation and removal by settling or filter-

*Of Vogt Brothers Mfg. Co., Louisville, Ky.

ing. The presence of carbon dioxide is especially objectionable in waters of low alkalinity. It is often good practice to aërate waters which have been treated with alum for coagulating purposes because carbon dioxide is liberated during coagulation. For a given alkalinity there is a limit of free carbon dioxide above which the water will readily dissolve protective carbonate scale within the piping of the distribution system. Should the interior of the piping not be otherwise coated or protected, this dissolving action of CO_2 upon the natural carbonate coating will expose new surfaces of iron. As a consequence corrosion troubles and "red water" complaints may follow. Where a pipe is coated with a protective carbonate scale and a water containing much free CO_2 is suddenly discharged into it the scale may become detached from the pipe by being partially dissolved, the water may become turbid and meters may be affected.

Hydrogen sulphide, sometimes present along with carbon dioxide, is offensive to the senses of taste and smell; but of all objectionable gases it is most easily removed by aëration. Sulphuretted hydrogen, pumped into the mains even in amounts as low as 3 p.p.m. may induce the growth of sulphur bacteria; the decay of these organisms may be productive of taste and odor problems more serious in nature than the presence of hydrogen sulphide itself. Smithville, Texas, after changing from air-lift pumping to the use of deep-well turbines without aëration encountered serious difficulty of this nature.

Professor F. J. Sette of the Virginia Polytechnic Institute studied impounding reservoirs and has plotted curves covering an entire season showing the carbon-dioxide and dissolved-oxygen content of the Pulaski reservoir in Virginia. His determinations indicate that in reservoirs of this type carbon dioxide and oxygen content are correlated inversely: as the dissolved oxygen content rises, the carbon dioxide content is lowered, like the operation of a see-saw. Sette states: "Therefore, the amount of carbon dioxide a water will contain will vary inversely to the dissolved oxygen content. Thus if water is well aërated it will approximate 100 per cent. of oxygen saturation and only 1 to 2 p.p.m. of carbon dioxide gas. While, if stagnant it may have no oxygen content and as much as from 20 to 30 p.p.m. of carbon dioxide."

The lesson to be learned is that in an impounded reservoir depleted oxygen means increased carbon dioxide and conversly increased oxygen means decreased carbon dioxide. Carbon dioxide is no friend to the waterworks superintendent except for recarbonation of caustic water after lime softening.

Algæ thrive in the presence of CO_2, clear water and sunlight. They may be destroyed by the toxic action of chlorine or copper sulphate. In water purification plants they may be removed or restricted in growth by the addition of artificial turbidity to the raw water of settling basins. This practice shuts off sunlight by making the water slightly opaque. Algæ growth can also be retarded by taking away their supply of CO_2 and in-

creasing the oxygen content through aëration of raw water entering sedimentation basins.

Aëration of Raw Water Combined with Mixing of Coagulant.

The fifth and major reason for aëration, one that has been overlooked until recent years, is its use in coagulation. Since aëration, as stated at the outset is a mixing process, that of finely dividing the air and intimately mixing it with water — or *vice versa* finely dividing the water and mixing it with air, it is a process which lends itself readily to the concurrent and simultaneous introduction of chemical coagulant. Many waters along the Eastern Coast of the United States are soft and of low alkalinity. They are often high in color, and these colors sometimes are difficult to coagulate and require unusual chemical treatment. It has been found that by combining the violent action of aëration with the simultaneous introduction of coagulant, thus increasing interfacial contact, the color will yield more readily. It has not been fully determined whether this is a physical change or a chemical change, but it has been demonstrated at Danville and Lynchburg, Va., and at Oshkosh, Wis.

Other Advantages Gained By Combining Aëration With Mixing.

If chemicals can be introduced into raw water in a manner that will accurately proportion and thoroughly diffuse them through the water by the violent agitation of aëration, a perfect mix will result. Efficient aëration and thorough diffusion of chemicals can be accomplished in one operation with a minimum expenditure for chemicals and a single-stage dissipation of power head.

There are several different types of aëration familiar to the waterworks man. In the cascade aërator water flows down an inclined plane often studded with plates forming a riffle board. In the coke-tray aërator as used at Memphis, Tenn., a number of trays or pans of coke are stacked above one another the water being discharged into the top tray, percolating through the coke and trickling on to each succeeding tray of coke. In the familiar spray-nozzle or spray-pond aërator the water is broken into fine drops or sprays which are thrown into the air for the exchange of gases. In the past, this type of aërator has been used most widely; but it requires a large head to obtain satisfactory results. In another form of aëration diffused air is blown into the water through a pipe grid or diffuser plates.

A Description of Aër-o-mix.

Aër-O-Mix is an aërating device of the diffused-air type. It was first used at the Waukegan, Ill. Filtration Plant which was put in operation on January 8, 1929 to treat Lake Michigan water. Air at atmospheric pressure is sucked in from the air intake manifold by the velocity of water flowing past hundreds of bronze air tubes — on the injector principle — into a

specially designed orifice or mixing throat. The velocity of the water in the down-draft tube is too great to allow the entrained air bubbles to es-

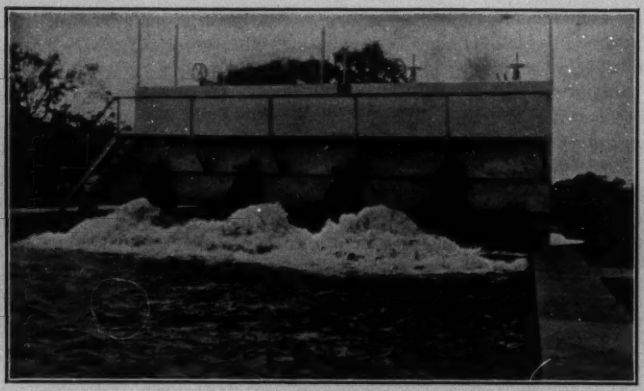

FIG. 1.—NASHVILLE, TENN., THREE 10 M.G.D. AËR-O-MIX UNITS.

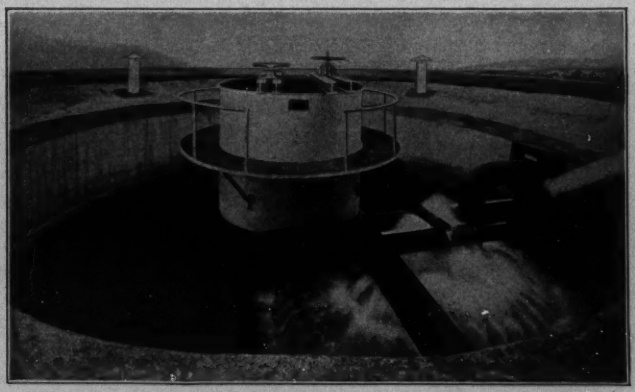

FIG. 2.—LYNCHBURG, VA., 6 M.G.D. AËR-O-MIX INSTALLATION.

cape. Because of the tendency of these bubbles to rise and the high velocity of the down-flowing water a violent agitation and thorough mixing result. The air bubbles are constantly being dispersed, forced downward and re-

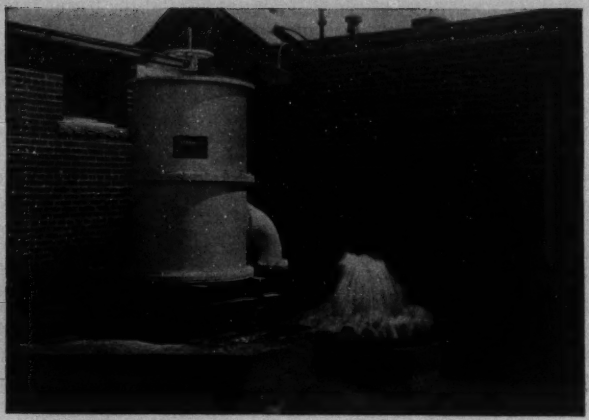

FIG. 3.—VALPARAISO, IND., 1½ M.G.D. AËR-O-MIX INSTALLATION.

FIG. 4.—BOULDER CITY, NEV., 1¼ M.G.D. AËR-O-MIX INSTALLATION.

duced in size due to the pressure of water above them. A large interfacial contact results. The mixture of air and water (and chemical when introduced) then rises through the riser pipe of the Aër-O-Mix U-tube and discharges in violent turbulence over the circular, herring-bone baffle studded

discharge plate a few inches above the water level in the basin. The entrained air is released, sweeping out with it the volatile gases including carbon dioxide and supplying fresh oxygen. If alum is used as a coagulant the CO_2 given off is also removed. Experience has proved that the three seconds of violent aëration in the U-tube are effective in taste and odor removal and color reduction when 8 feet of operating head can be obtained. Aëration however is not completed when the water leaves the discharge plate. The larger air bubbles have been released and pass off into the atmosphere, but the smaller bubbles continue to rise in the basin for some ten or fifteen minutes. This slow rise of the fine bubbles continues the process of aëration—and where coagulant has been employed is an aid to floc formation. Aër-O-Mix is designed on the principle that it is cheaper from an operating standpoint to carry air down with the water and intimately mix it with the water than it is to break the water up into fine drops by forcing it through nozzles under high head. A number of Aër-O-Mix installations are shown in Figures 1 to 4.

Mr. Richard F. Wagner, Director of Safety & Water at Lynchburg, Va., has made the following statements with regard to the operation of Aër-O-Mix during 1931.

1. Difference between previous annual power costs, and the fixed charges on the Aër-O-Mix investment, results in saving a net sum of approximately $1 600 for the year.

2. A potential saving in the cost of chemicals because of better mixing facilities and consequent reduction in the amount of chemical dose, and also improved sedimentation.

3. Raw water may now be drawn from lower levels in Pedlar Lake where temperatures are lower, thus giving our consumers a cooler supply. Such water in the summer time is usually charged with iron in solution, and Aër-O-Mix oxidizes the dissolved ferrous into the insoluble ferric iron, which is coagulated and subsequently removed by filtration.

4. Aëration is now a continuous every day process rather than being used, as was formerly the case, during a short period of the year only, thus being an important factor at all times towards the production of a palatable supply.

While the usual characteristic tastes and odors were present in the raw water during the summer of 1931, Aër-O-Mix completely removed such objectionable qualities, coincidently reducing the amount of carbon dioxide materially.

Discussion.

Robert Spurr Weston.* The question of prevention of odors is a very broad one. We have a whole range of substances in water which produce odors, ranging from hydrogen sulphide, which is a very light and diffusible gas, down to soluble vegetable matters and further to products of industrial waste discharges, which are almost insoluble, and which are the hardest to take out of the water.

You will remember in the old days to test the gasoline they took a saucer of gasoline and threw it into the air. If it did not hit the ground it was good gasoline. Modern gasoline will not do that.

I think we have an analogous condition among the odors. Some are easily dissipated by aëration, and some a vacuum cleaner would not take out. We must therefore have different treatments for different odors. We must have it that way in the nature of things.

There are three principal gases which we take out by aëration,— hydrogen sulphide, carbon dioxide, and methane. The hydrogen sulphide and the methane are comparatively easy to dissipate by aëration; the carbon dioxide is a little more difficult to remove.

Next there is a class of bodies which are not unlike turpentine in character,— that is, they are heavy but still volatile. They are in the nature of essential oils, and they are the oils which are produced by the growth of algæ. These also are removed by aëration but with some difficulty.

Third in order is a class of vegetable compounds which are present in a great many of the New England waters, which are removed in part by aëration. Just as one can distill off the lighter portion of petroleum and get some of the paraffin residuum left behind, so with these bodies one can get off the lighter part of the odor and the heavier part will still remain in the water.

Finally there are substances such as are found in waters such as that from the Ludlow Reservoir, for example, or from a great many of our New England upland streams, and those of the Middle Atlantic states, which are polluted with sewage and industrial wastes. These waters must be treated with chemicals or with solids. By chemicals I mean chlorine and ammonia which may oxidize and change over the objectionable into unobjectionable tastes. By solids I mean absorbing substances such as activated carbon and clay. Clay has been used at Chester, Pa. On account of the shortening of filter runs with the use of activated carbon it could not be used, and clay has been substituted as an adsorbent with a considerable degree of success in treating a water which is extremely polluted. Chester is 17 miles below Philadelphia and draws water from the Delaware which receives the sewage of Philadelphia and the industrial wastes from the plants along the shores of the river.

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MECHANICAL CONDITIONING OF TREATED WATERS.

BY R. S. RANKIN.*

[*Read September 30, 1932.*]

Recent developments in mechanical mixing devices for water-filtration plants give indications that, in comparison with the present methods, material savings in chemical consumption and a water better prepared for subsequent treatment can be secured. The aim of any mixing device is assumed here to be one which intimately mixes the applied chemicals with the water and, what is considered more important, maintains this mixing action until effective coagulation or flocculation is completed. Water which has been effectively prepared in the mixing tanks should be ready as it enters the subsidence unit for the settling of all flocculated material without further continuation of the reaction step. Broadly speaking, this is probably the aim of all present designs of mixing tanks, and represents the optimum conditions obtainable.

Types of Mixing Devices. Mixing devices may be classified as follows:

1. Plain, or non-mechanical.
   (a) Around-the-end type of baffled basin.
   (b) Under-and-over type of baffled basin.
   (c) Hydraulic jump type.
   (d) Spiral flow type.
2. Mechanical.
   (a) Air agitation.
   (b) Vertical shaft paddle type.
   (c) Horizontal shaft paddle type.

These types (Fig. 1) are probably too well known to need more than cursory description and comment.

The around-the-end type of baffling is probably the oldest type in use today, excepting installations where chemicals are applied directly to pump suctions or inlet channels to settling tanks. In small plants it is difficult to construct this type with passageways of proper size to maintain desired velocities, and in all plants loss of head through this type of basin is an important factor. More than one plant has required radical changes in baffle arrangement to overcome head-loss difficulties not considered by the designer. Any change in quantity flowing through the around-the-end type of mixing chamber affects the velocity proportionately and consequently the effectiveness of mixing.

The under-and-over type of baffling is probably better adapted to smaller plants, because for large plants the construction becomes complicated and loss of head reaches impractical limits. In this type, also,

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velocity is affected directly by changes in quantities passing through the basin.

The hydraulic jump has found limited application in plants and apparently produces a rapid and thorough mixing. However, the period of contact is so short and the violence of action so great that complete flocculation can scarcely be accomplished. In practice, better results can

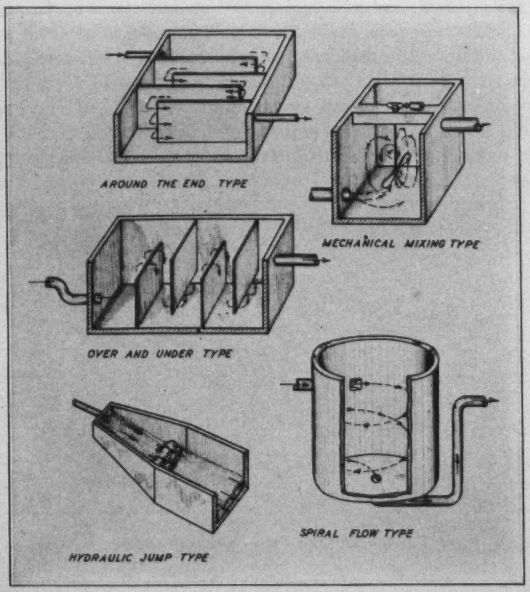

FIG. 1.—CONVENTIONAL TYPES OF MIXERS FOR WATER TREATMENT.

probably be obtained by following the hydraulic jump with additional mixing capacity of some other type.

The spiral flow type of mixing basin, in which the water enters tangentially and is taken off at the center of the bottom, has been used in several places. Although suitable velocities can be maintained, the principles involved are opposed to all theory, in that the velocity of mixing is constantly increasing from influent to the effluent point, where on the contrary a reduced velocity is desirable. Loss of head is also appreciable in the spiral flow type. The path taken by the water in a circular spiral flow unit appears too regular and uniform for ideal intermixing and proper floc formation.

Under mechanical mixing devices, compressed air may be included as probably one of the early forms of this type. Compressed air may be convenient in small installations, but as the size of plant increases, its use becomes uneconomical when compared with other types of mixing. The use of air may possibly bring about a coalescence of particles, or flocs, and thereby increase the settling rate, but on the other hand the presence of entrained air bubbles may hinder the settling. The fact remains, however, that air agitation or mixing is comparatively more expensive than agitation by other mechanical means. In this connection aëration of the water for release of gases is not considered, as that is usually a separate step in the treatment.

Paddle agitation or mixing is old in industry and has found considerable application in water plants in the last ten or twelve years. Such paddles are usually mounted on a vertical shaft, so that the impeller rotates in a

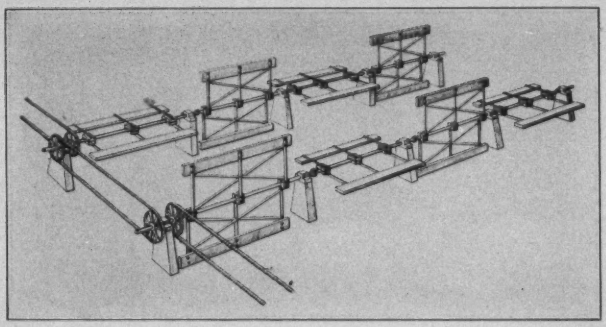

FIG. 2.—DUPIEX TYPE OF FLOCCULATOR.

horizontal plane. Many variations may be found, from relatively small impellers revolving from 30 to 40 r.p.m. up to impellers two-thirds the tank diameter revolving from 4 to 12 r.p.m. One type has been used in which a short draft tube encloses an impeller of large diameter. This arrangement, combined with suitable baffles, is designed to force all the water passing through the basin through the zone of impeller action.

Many variations in size and shape of paddles have been used, but in all of them uniform flocculation conditions are not easy to maintain if flow conditions vary. Short-circuiting is usually present in this type of unit, although it is considerably overcome by the use of multiple units with baffles or walls interposed between units.

Another type of mechanical mixer recently developed is of the paddle type, but it differs from the usual type in that the shaft is horizontal, and a series of paddles, parallel to the shaft are connected thereto by radial

arms. It is installed in a rectangular tank and rotated at relatively slow speeds. The diameter of the circle of rotation is only slightly less than the depth of water in the tank. The paddles may be installed in the basin with the shaft lengthwise or crosswise. When placed lengthwise, one or more units may be used to give mixing to the entire tank cross section. When placed crosswise to the direction of flow, two or more shafts with paddles are operated in series, the number depending on the capacity of the mixing tank. The length of paddles in this case is, of course, the width of the tank. Three installations have been or are being made, and on one of them practically a year's operation has demonstrated some unusual feature. The device has been named the Flocculator, in order to describe its true function and also to differentiate it from other mechanical mixers. Further details will be discussed later.

Time of Mixing. The time required for mixing chemicals with water and preparing the mixture for subsequent sedimentation of the precipitated material has not been appreciated until recently, except by a few engineers. The general effects of too short a period of preparation are wastage of chemicals, incomplete sedimentation, shorter filter runs and water poorer in quality.

Every water treatment problem is in a class by itself, but some generalization in type of treatment is permissible, and a rough classification of mixing requirements can be given.

Treatment of water with chemicals has for its primary object one of the following:

1. Removal of dissolved solids.
2. Removal of fine or colloidal turbidity.
3. Removal of color.

The water undergoing treatment may be classified as hard, medium or soft, so that many combinations are theoretically possible, but since, in practice, treatment for removal of dissolved solids is associated usually with softening, and color and turbidity removal are associated with coagulation, the possible combinations are greatly reduced in any one plant. The commercial chemicals customarily used to remove objectionable qualities are lime, alum, soda ash, ferrous sulphate and, more recently, ferric chloride. With the exception of lime, the time for actual completion of reaction with water is probably not over two or three minutes. But the mixing step has other functions than completion of the chemical reaction. One is to build up flocs of precipitated material of uniform size so that they are all ready to settle at approximately the same rate. Another function is to cause each floc particle to sweep through the water and collect the impurities. All of this takes time, and only with proper time allowance can good results be secured. Actually, two time intervals are requisite to good operation: the first an interval of rapid mixing of one to five minutes' duration and the second a longer interval of slow mixing. The duration of the

second mixing period depends on the treatment, but broad requirements for best results are as follows:

For coagulation with alum, ferric chloride, etc., 30 to 60 minutes.
For water softening using lime, 60 to 90 minutes.

Many operating plants do not have these detention periods, particularly those simply coagulating the water, but it has been repeatedly demonstrated that the longer periods are better from every standpoint. This fact is being reflected more and more in recent design.

Power Requirements for Mixing. Mixing in any form consumes power, either in the form of excess pumping head for plain mixing tanks or motor power for mechanical mixers. In a tank having 60-minute detention a plain baffled basin can easily require 2 or 3 ft. of head. At a pumping efficiency of 65 per cent., about 5 k.w.h. of electric current are required to raise one million gallons of water one foot. Therefore, the 2 or 3 ft. of head will require 10 or 15 k.w.h. per million gallons.

In the spiral flow tank the detention periods are usually much less than 60 minutes, but it is safe to assume that head requirements will probably equal or exceed those of the baffled tank for similar periods.

Compressed-air agitation is probably the most expensive, and, assuming about 50 per cent. of the requirements for sewage agitation, about 25 k.w.h. per million gallons, will be consumed for a 60-minute period.

Ordinary paddle mixers of the vertical shaft type have been estimated to require about 8 k.w.h. per million gallons for the same period.

The Flocculator described requires about 6 k.w.h. per millon gallons for a unit of average diameter having a capacity of 60 minutes' detention.

Summarizing, the power requirements for various types of mixers are estimated approximately as follows:

Type of Mixer.	Kilowatt Hours Required for Mixing Period of 60 Min. per Million Gallons.
Plain Baffled Basin	10 to 15
Spiral Flow	10 to 15 (Minimum)
Compressed Air	25
Paddle Mixer, Vertical Shaft Type	8
Flocculator	6

Principles of Flocculator. In developing the Flocculator, a combination of several important principles has been secured. These may be summarized as follows:

1. Uniform mixing throughout entire period.
2. Efficient mixing, regardless of low flowing-through velocities.
3. Variation in degree of agitation, depending on type of floc being handled.
4. Minimum short-circuiting of flow.
5. Ease of adaptation to existing plants.
6. Negligible loss of head.

7. Low power requirements, and hence low operating cost.
8. Water better prepared for subsequent treatment.
9. More efficient use of chemicals, hence lower chemical consumption.
10. General improvements in plant performance.

Uniform mixing is obtained because the number and speed of the paddles determines the completeness of the mixing step. Since the velocity of the water across the basin has no bearing on the speed of paddles, it is evident that proper mixing is entirely under the control of the operator, who can regulate the speed at will.

If the floc is a fragile alum one, the speed of the paddles may be reduced or regulated so as to prevent breaking these particles, and, instead, build them up to a maximum, uniform size. If, on the other hand, a heavy, tenacious floc is formed, one which requires higher velocities to keep in suspension, the paddle speed may be changed to suit. Any type of floc may be handled by the possible variations in this type of mixer. Short-circuiting is practically impossible, as the zone of paddle action covers the entire cross-section of the mixing basin for a length readily determined by number and spacing of paddles.

This flocculating device can be readily adapted to most existing basins, about the only requirement being that they are rectangular in cross-section. Frequently, when existing mixing tanks are too small, as they usually are, or not readily adaptable, it is preferable to install the Flocculator in the first section of the coagulating basin. The existing mixing tank can then be adapted for a rapid mixing step, and the flocculation performed in the first section of the coagulation basin properly equipped. This construction has a decided advantage. The water leaves the Flocculator and enters the sedimentation basin over the entire tank cross-section. Certainly, no more ideal conditions could be established for proper sedimentation.

The Flocculator appears to build all the flocs to a uniform size, and this uniformity can be observed to some extent with the eye, but better proof of uniformity is obtained by observing the settling rate. Flocs of non-uniform size automatically classify themselves in any sedimentation test. The heavier ones settle out more rapidly and leave the lighter ones behind, with only a thin layer of completely-cleared water at the surface. In observing a sedimentation test of water treated in a Flocculator, the particles all appear to settle at a uniform rate, leaving a larger clear upper zone.

Power requirements are always of prime importance, because power loads in a water plant are continuous, day in and day out. Whatever their magnitude, they constitute an item deserving consideration. The Flocculator is a slow-moving device, and power requirements are definitely low. As stated previously, about 6 k.w.h. per million gallons is a fair estimate of consumed power for a 60-minute mixing period. At 1c per k.w.h., this amounts to 6c per million gallons for this period of mixing, which is not a serious item, in comparison with other expenses.

Better-prepared water means water that clarifies better in the sedimentation basin, and this in turn means better water to send to the filters. Better water on the filters may mean longer filter runs, higher rates of filtration, lower wash-water consumption or higher plant output. Better-prepared water can conceivably increase the output of under-capacity plants to such a degree that enlargements can be postponed for a time.

Savings in chemicals is perhaps the most pronounced result of the use of this device. Chemicals used for coagulation can be cut from 10 to 30 per cent., in most plants, by this more efficient mixing method, and this saving would be an appreciable annual item in the average plant. There are some exceptions to this general statement on probable savings. One is in plants which now are not using sufficient chemical dosage to effect proper flocculation. This condition probably exists in not a few plants, and the cause is possibly faulty operation or lack of knowledge. But, in this type of plant, proper and adequate mixing would certainly yield better results than at present. Another exception is in plants which are using a correct chemical dosage, based on analytical results in the laboratory, and reductions are possibly impractical. In such plants, again, it can be stated that better-prepared water can be secured by improved flocculating methods now available. In general, however, extensive work done in various plants throughout the country with test units shows that considerable savings in chemicals can be made. These savings will frequently pay for installation costs in a year or two, to say nothing of the benefits of the improved quality of water.

Operating Results. Results of the operation of this type of flocculating device have been obtained at a number of places from field tests with a laboratory unit, and from a full-size installation at Richmond, Va. The field tests with laboratory units give only indications of chemical savings, but they are of interest and some of them are recorded in Table 1.

TABLE 1.—RESULTS ON CHEMICAL CONSUMPTION IN FIELD TESTS WITH SMALL FLOCCULATOR.

PLACE.	PRESENT CONDITIONS.				RESULTS INDICATED BY FLOCCULATOR TEST.		
	Flow M.G.D.	Chem. Dosage Grains per gal.		Mixing Time Min.	Chem. Dosage. Grains per gal.		Mixing Time.
		Alum.	Lime.		Alum.	Lime.	
E. St. Louis, Ill.	17.0	1.0	0.3	7.4	Reduction 25%		30
Covington, Ky.	10.	1.4	0.6	None	0.9	0	30
Alton, Ill.	3.8	1.5	0.7	None	1.0	0	60
Danville, Ill.	4.5	2.15	0	6	1.0	0	60
New Brunswick, N. J.	5.0	1.0	0	None	0.75	0	30
Winston-Salem, N. C.	12.0	3.0	0	15	1.75	0	15

These few results indicate the possibilities in chemical savings, but the figures should of course not be prorated to an entire year, because most of the data relate to conditions at the plant at the time the test was made.

The question naturally arises as to the reliability of application of such laboratory results to full-scale tests. Results at Richmond, Va., throw some light on this question. At Richmond, Va., four full-size Flocculators have been in use for nearly a year. A description of this installation and operating results for four months are given in Water Works and Sewerage, April, 1932, in an article by M. C. Smith, Engineer of Water & Electricity, Richmond, Va. In this article a comparison between laboratory test-runs and full-scale operation shows that to accomplish the same degree of coagulation the full-scale operation actually required 20 per cent. less chemicals than laboratory results indicated.

Since Mr. Smith's paper was prepared he has secured additional data for several months. The average results for the entire 8 months' period since the Flocculators were installed compared with a similar period prior thereto are given in Table 2.

TABLE 2.—COMPARATIVE FILTER PLANT OPERATION BEFORE AND AFTER INSTALLING FLOCCULATORS AT RICHMOND, VA.

Results are monthly averages.

	Nov. 1930–July 1931			Nov. 1931–July, 1932.		
	Ave.	Max.	Min.	Ave.	Max.	Min.
Turbidity Raw Water—p.p.m.	66.8	197.	14.0	67.1	130.0	25.7
Color Raw Water—p.p.m	40.5	59.7	28.9	34.9	72.7	3.0
Color Finished Water—p.p.m.	3.8	4.6	2.5	3.1	4.0	2.2
Alum Dosage Grain per gal.	3.48	5.4	2.36	2.09	2.78	1.62
Alum Residual Finished Water—p.p.m.	0.121	0.27	0.024	0.040	0.106	0.022
Filter Runs—Hours	53.93	98.2	24.3	60.06	87.1	40.9

Comparison of these results during the two periods shows that with a raw water having similar characteristics, a finished water of better quality was turned out with the use of the Flocculator with a saving in alum of 1.39 grains per gallon, about a 40 per cent. reduction. At the Richmond plant this saving represents about 4 000 lb. of alum per day.

The increased settling rate of the floc is not shown in the table, but prior to the installation of mixing units, the precipitate settled out fairly uniformly throughout the 700 ft. of basin length, while afterwards the floc settled out in a heap within 50 ft. off the last paddle and the remainder of the basin was clear.

Variations in quality of raw water at Richmond are frequent and formerly much care had to be taken to cope with these conditions. Now apparently they can be handled with practically no operating adjustments other than seasonal.

Conclusions. Several points in regard to mechanical conditioning of water may be stated as a result of field tests, actual plant operation and also a perusal of data in current literature.

1. Present periods of mixing are generally too short, a period of 30 to 60 minutes for coagulation and 60 to 90 minutes for softening should be used.
2. Present use of chemicals for coagulation can probably be reduced about one-third in the average typical plant, or present chemical dosage can produce materially better results through use of adequate mixing periods in conjunction with efficient flocculation equipment.
3. Present types of mixing basins, both plain and mechanical, are difficult to operate to secure prolonged mixing without the occurrence of either short-circuiting, breaking up of floc, high loss of head or power consumption, or insufficient mixing effect.
4. The Flocculator, with all its variations, shows promise of ability to overcome many of the objections of present practice and to produce the best results at minimum cost of operation.
5. Laboratory model Flocculators appear to give results which can be readily translated into full-scale operation.

Acknowledgment. The writer wishes to acknowledge the free use of articles in current literature, particularly those by John R. Baylis, on mixing basins.

MAXIMUM DAILY AND HOURLY WATER CONSUMPTION IN AMERICAN CITIES.

BY A. PRESCOTT FOLWELL.*

[*Read September 28, 1932.*]

Most of the available data on monthly, daily and hourly maximum rates of consumption of water in United States cities are rather old or limited in scope. But such consumption figures, either known or assumed, are necessary in designing almost every feature of a water-works plant. The author believed, therefore, that reliable information of this sort, if it could be secured, would be of real value. Through questionnaires, the periodical of which he is editor secured information from 654 United States municipalities, located in all of the 48 states. The information furnished by a number of these cities was not based on accurate records or was not sufficiently complete to be of value. For these and other reasons the study was limited to the questionnaires received from 361 cities, all of which appeared to keep accurate records, and most of them to have modern means available for measuring the flow. As reported by the water-works officials which furnished them, 75 per cent. of the figures were derived from meter readings, 33⅓ per cent. being recorded by Venturi meters, the others not specified; 18 per cent. were from pumping records; 5½ per cent. were estimated. (See Table 5.) This group of 361 cities ranged in size from Detroit, Mich., with a population of over 1½ million, to Helmetta, N. J., which reported a population of 700.

As the study progressed, many problems arose apart from the one of digesting the great mass of information contained in these 654 reports, sorting, arranging, figuring rates and percentages, etc. Because of the great amount of work involved, this paper is little more than a progress report. More time will be required to make a complete study of the data and fill in gaps in the information at hand.

One of the problems was connected with population as a basis of per capita consumption. We might say that any town, for the purpose of such a study, has three populations: The population claimed by the Chamber of Commerce; the population given by the Census Bureau; and the population served by the water department. As population grows more rapidly than the Census Bureau moves, the optimistic figures of the Chamber of Commerce may be approximately correct. (As this study deals with consumption figures for 1931 or 1930–1931, the 1930 Census figures probably are not far wrong, and are used.) The census figures may greatly exceed the consumer figures; some of our southern cities, for example, serve but

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a portion of their population, a considerable percentage, in some cases, obtaining their supplies from wells and springs. On the other hand, the consumers may include non-citizens. In most of the tables accompanying this paper the rates are figured on the basis of population served as reported by the water-works superintendent; but in tables 2, 3 and 4, census figures are used.

Month of Greatest Consumption. Of the 361 cities which furnished sufficient data to form a basis of study, 348 named the month of maximum consumption. The result is given in Table 1, from which it will be seen that almost exactly 80 per cent. of the cities reporting show their maximum draft to occur in July or August.

Maximum Monthly Consumption. The maximum monthly consumption varies widely. In Massachusetts, for instance, the lowest reported was 105 per cent. of the average, for the month of August for New Bedford; while another Massachusetts city reported 190 per cent. of the average, for July. The combined results of the cities reporting, based on the total consumption for the average month and the total consumption for the maximum month, showed that the maximum-month consumption averaged 124 per cent. of the average month.

Maximum Daily Consumption. Seventeen cities of more than 100 000 population gave figures for their maximum daily consumption which it seemed desirable to include in this study. Their population, number of consumers, average and maximum daily per capita consumption are given in tables 2 and 3. The maximum daily consumption of these averages 153 per cent. of the mean daily, only three exceeding 160 per cent. and three being less than 130 per cent.

Figures of maximum daily per capita consumption are given in Table 4 for seventeen New England cities of 20 000 population or less. The results show a maximum consumption of 166 per cent. of the average; but the average per capita consumption is 68 g. p. d., as compared with 117 g. p. d., the average for cities of more than 100 000 population. The averages of maximum daily per capita consumptions are 100 g. p. d. for small New England cities and 175 g. p. d. for the large cities.

The percentage ratios of maximum to average daily consumption for the several districts, in order of magnitude, are: East North Central — 196; West North Central — 188; West South Central — 185; Pacific — 175; Mountain — 173; So. Atlantic — 158; New England — 155; Middle Atlantic — 150; East South Central — 149. The average for the whole United States (284 cities) is 176 per cent.

Maximum Hourly Consumption. The number of cities that could give accurate figures concerning the maximum hourly consumption was, of course, rather limited, aggregating 94 for the entire country, after weeding out all the doubtful ones. As might be expected, the variations are wider than in the case of daily maxima. Many things can be considered as influencing this, including major breaks in lines, fires in the case of the

TABLE 1.—Month of Greatest Consumption in 348 Cities.

January	10	May	4	September	17
February	2	June	18	October	6
March	7	July	193	November	1
April	1	August	86	December	3

TABLE 2.—Population Served, Census Population and Daily Per Capita Consumption — Large Cities.

City	Population		Daily Per Capita Consumption g.p.d.	
	By Census Bureau	Served*	Total Population	Consumers
Detroit, Mich.	1 678 000	1 678 000	144	144
Buffalo, N. Y.	590 000	590 000	192	192
Milwaukee, Wis.	578 000	648 000	146	131
Minneapolis, Minn.	460 000	460 000	122	122
Cincinnati, O.	451 000	500 000	127	114
Louisville, Ky.	308 000	330 000	138	129
Atlanta, Ga.	270 000	300 000	115	103
Providence, R. I.	253 000	320 000	99	77
San Antonio, Tex.	231 000	256 000	99	89
Dayton, O.	200 000	230 000	117	101
Oklahoma City, Okla.	185 000	200 000	74	69
Hartford, Conn.	164 000	208 000	109	87
Flint, Mich.	156 000	156 000	89	89
Springfield, Mass.	150 700	150 700	102	102
Long Beach, Calif.	145 000	145 000	107	107
Tulsa, Okla.	140 000	140 000	129	129
Knoxville, Tenn.	122 500	122 500	72	72
Average			117	109

*As reported by water works official.

TABLE 3.—Maximum Daily and Hourly per Capita Consumption—Large Cities on basis of Census Population.

City	Daily Gallons	Maximum % of Average	Hourly Gallons	Maximum % of Average
Detroit, Mich.	215	150	...	...
Buffalo, N. Y.	248	129	...	...
Milwaukee, Wis.	225	154	328	226
Minneapolis, Minn.	272	222	396	324
Cincinnati, O.	191	150	254	200
Louisville, Ky.	188	136	...	...
Atlanta, Ga.	153	133	230	200
Providence, R. I.	127	128	...	...
San Antonio, Tex.	147	149	208	210
Dayton, O.	169	153	...	...
Oklahoma City, Okla.	178	240	247	333
Hartford, Conn.	140	128	213	195
Flint, Mich.	143	161	...	...
Springfield, Mass.	134	131	211	203
Long Beach, Calif.	165	154	...	...
Tulsa, Okla.	186	144	...	...
Knoxville, Tenn.	106	148	156	216
Averages	175	153	249	234

TABLE 4.—Maximum Daily per Capita Consumption—New England Cities of 5 000 to 20 000 Population.

City	Population (Census Bureau)	Daily Consumption		
		Average	Maximum Gallons	Maximum % of Average
Calais, Me.	5 500	94	139	148
No. Andover, Mass.	6 680	63	116	207
Mansfield, Mass.	6 800	67	129	194
Franklin, Mass.	7 000	64	99	154
Turners Falls, Mass.	8 000	102	145	142
Putnam, Conn.	8 000	93	163	175
Hudson, Mass.	8 500	46	88	192
St. Johnsbury, Vt.	9 000	123	167	135
Reading, Mass.	10 500	41	57	141
Amesbury, Mass.	12 000	55	86	156
Needham, Mass.	12 500	58	101	169
Webster, Mass.	12 800	47	65	139
Natick, Mass.	13 400	58	107	185
Danvers, Mass.	13 465	92	173	188
Abingdon, Mass.	14 000	41	94	229
Greenfield, Mass.	15 500	86	103	120
Marlborough, Mass.	16 000	44	72	164
Gardner, Mass.	20 000	43	70	163
Averages	11 091	68	110	166

TABLE 5.—MAXIMUM HOURLY PER CAPITA CONSUMPTION, 96 CITIES OF ALL SIZES, BY GEOGRAPHICAL DIVISIONS, ON BASIS OF NUMBER OF CONSUMERS.

City	No. of Consumers	Av. Consumption per day per Consumer	Maximum Hourly Consumption Gal. per Consumer	Maximum Hourly Consumption % of Average	How Measured
New England States					
Hartford, Conn.	208 000	87	7.0	192	M
Springfield, Mass.	150 700	102	8.8	200	V
Natick, Mass.	13 400	57	17.9	753	M
Rockford, Mass.	6 000*	58	5.2	216	P
Av., more than 10 000		*76*	*9.7*	*340*	
Putnam, Conn.	8 000	93	10.9	281	P
Hudson, Mass.	7 700	51	5.5	258	V
Av., less than 10,000		*72*	*8.2*	*270*	
Middle Atlantic States					
Shamokin, Pa.	65 000	121	7.7	152	M
Auburn, N. Y.	48 600	116	8.6	178	V
Fulton, N. Y.	12 800	62	5.6	218	M
Herkimer, N. Y.	10 854	77	9.2	288	M
Av., more than 10 000		*94*	*7.8*	*209*	
Ashland, Pa.	8 000	90	6.2	166	E
Beaver, Pa.	5 665	132	20.1	366	F
Catasauqua, Pa.	5 000	140	13.2	226	V
Av., less than 10 000		*121*	*13.2*	*253*	
East North Central States					
Milwaukee, Wis.	648 000	131	12.3	226	V
Cincinnati, O.	500 000	114	9.5	200	P
Rockford, Ill.	89 200	82	10.9	329	V
Saginaw, Mich.	80 600	138	11.9	208	V
Evanston, Ill.	79 700	131	14.2	257	M
Springfield, O.	70 000	159	14.5	220	P
Racine, Wis.	67 500	94	12.0	309	M
Oak Park, Ill.	65 000	94	9.2	235	M
Kalamazoo, Mich.	55 416	93	9.9	279	V
Battle Creek, Mich.	50 000	93	19.6	512	V
Rock Island, Ill.	38 000	104	8.9	212	P
Elgin, Ill.	37 000	60	7.5	300	RD
Ann Arbor, Mich.	36 000	110	18.8	410	HM
Waukegan, Ill.	33 500	120	14.9	304	M
Port Huron, Mich.	32 000	252	28.7	272	V
Middletown, O.	30 000	90	6.9	185	V
Harvey, Ill.	30 000	76	5.5	174	V
Mishawaka, Ind.	27 000	71	12.1	416	M
Wausau, Wis.	20 728	110	12.0	275	M
Bloomington, Ind.	18 000	94	5.7	142	V
Holland, Mich.	15 200	95	22.7	575	P
Cairo, Ill.	15 000	125	12.7	244	M
Escanaba, Mich.	14 516	99	9.6	233	P
Mattoon, Ill.	14 000	77	6.0	187	
Menominee, Mich.	11 000	116	34.1	715	V
Two Rivers, Wis.	11 000	70	13.6	466	V
Watertown, Wis.	11 000	70	13.6	473	V
Ashland, Wis.	10 500	139	24.5	404	P
Whiting, Ind.	10 175	265	19.6	180	V
Ypsilanti, Mich.	10 000	111	13.5	293	P
Av., more than 10 000		*112*	*13.7*	*309*	
Menasha, Wis.	9 200	194	19.6	256	M
Conneaut, O.	8 460	150	12.0	189	V
St. Joseph, Mich.	8 341	110	20.0	450	P
Sturgis, Mich.	8 000	100	17.2	419	M
Kaukauna, Wis.	6 581	40	9.0	550	M
Madison, Ind.	6 522	213	22.1	250	M
Petoskey, Mich.	6 500	91	18.5	495	V
Lebanon, Ind.	6 000	69	7.5	259	M
Lake Forest, Ill.	5 600	262	53.4	496	V
Wilmington, O.	5 400	36	7.3	493	P
Vandalia, Ill.	5 000	85	12.0	340	P
Orrville, O.	4 600	73	10.0	332	P
Stoughton, Wis.	4 500	56	11.2	487	SM
Montpelier, O.	3 800	93	13.8	356	E
Medina, O.	3 400	73	8.9	291	P
Av., less than 10 000		*110*	*16.2*	*377*	
West North Central States					
Minneapolis, Minn.	460 000	124	16.5	320	M
Duluth, Minn.	101 000	95	8.5	212	V
Sioux City, Ia.	80 000	78	6.0	188	M

Springfield, Mo.	70 000	60	4.1	163	V
St. Cloud, Minn.	21 000	54	19.0	874	M
Rochester, Minn.	20 600	54	6.1	270	M
Winona, Minn.	19 000	80	20.8	632	V
Beatrice, Neb.	10 000	81	12.0	355	M
Av., more than 10 000		*78*	*11.6*	*377*	
Centerville, Ia.	8 600	58	4.2	140	M
Fulton, Mo.	8 000	52	8.0	370	M
Carrol, Ia.	4 000	97	12.0	296	M
Av., less than 10 000		*69*	*8.1*	*269*	
South Atlantic States					
Atlanta, Ga.	300 000	103	8.6	200	M
Greensboro, N. C.	45 000	90	7.4	197	M
Raleigh, N. C.	40 000	82	8.3	212	V
Orlando, Fla.	27 000	90	7.7	206	M
Gastonia, N. C.	20 000	69	5.0	175	V
Av., more than 10 000		*87*	*7.4*	*198*	
Kings Mountain, N. C.	5 000	57	8.0	335	V
Cheraw, S. C.	3 575	57	4.7	197	E
Av., less than 10 000		*57*	*6.3*	*266*	
East South Central States					
Knoxville, Tenn.	122 500	72	6.5	216	V
Canton, Miss.	4 750	50	8.8	457	P
West South Central States					
San Antonio, Tex.	256 000	89	7.8	210	M
Oklahoma City, Okla.	200 000	69	8.3	288	V
Wichita Falls, Tex.	40 000	90	10.4	277	M
Av., more than 10,000		*83*	*9.6*	*272*	
Blackwell, Okla.	8 500	157	23.5	360	M
Crockett, Tex.	4 600	45	3.2	173	M
Av., less than 10 000		*101*	*13.3*	*267*	
Mountain States					
Tucson, Ariz.	36 000	130	23.0	433	M
Missoula, Mont.	16 000	528	43.7	200	M
Twin Falls, Ida.	11 000	269	27.3	244	M
Av., more than 10,000		*309*	*31.3*	*292*	
Roswell, N. M.	9 000	185	20.0	260	V
Alamosa, Colo.	4 000	120	18.8	375	P
Av., less than 10 000		*152*	*19.4*	*317*	
Pacific States					
Tacoma, Wash.	108 100	311	27.3	209	E
Sacramento, Calif.	87 000	270	24.4	217	V
Anaheim, Calif.	12 000	108	19.1	431	M
Marshfield, Ore.	10 000	119	13.2	221	V
Av., more than 10 000		*202*	*21.0*	*270*	
Lodi, Calif.	7 500	357	53.4	360	P
Red Bluff, Calif.	4 000	355	45.0	305	E
Av., less than 10 000		*356*	*49.2*	*332*	

E—Estimated. F—Electric flow meter. M—Metered. HM—House meters. P—Pumpage. RD—Reservoir displacement. SM—Station meters. V—Venturi meter.
* Permanent population, 4 000; summer (3 months) 12 000.

TABLE 6.—Maximum Hourly Consumption. Averages, by Districts, of Places of More Than and Less Than 10 000 Population.

	Average Daily per Capita Consumption		Maximum Consumption per hour			
			Gallons per capita		% of Average	
District	More than 10 000	Less than 10 000	More than 10 000	Less than 10 000	More than 10 000	Less than 10 000
New England	76	72	9.7	8.2	340	270
Middle Atlantic	94	121	7.8	13.2	209	253
East North Central	112	110	13.7	16.2	309	377
West North Central	78	69	11.6	8.1	377	269
South Atlantic	87	57	7.4	6.3	198	266
East South Central	72	50	6.5	8.8	216	457
West South Central	83	101	9.6	13.3	272	267
Mountain	309	152	31.3	19.4	292	317
Pacific	202	356	21.0	49.2	270	332
United States	115	117	13.3	15.4	298	330

smaller communities, use of water by industries, sprinkling lawns and gardens, seasonal tourists, etc.

As is shown in Table 5, the maximum rate of consumption per person per hour varies from around 3 gal. per hour up to a maximum of more than 50; but the average is around 14 gal. per hour. Generally speaking, it appears that the maximum hourly rate approximates 310 per cent. of the average in most of the cities, exceeds 400 per cent. in twenty-one, and is less than 200 in seventeen.

In Table 5 the figures for hourly consumption (on the basis of number of consumers) are classified geographically and are further separated according to size of city as pertaining to communities of more than and less than 10 000 population. The averages of figures for each classification are given in Table 6. The average per capita consumption in the East South Central states is apparently the least of any section of the country, followed in order by the New England, West North Central and South Atlantic states. The latter vary but little — between 74 and 78 g.p.d. Then come the West South Central with 91, Middle Atlantic with 107, East North Central with 111, Mountain with 230, and Pacific with 250 g.p.d. Maximum-hour consumption expressed as percentage of the average varies from 220 in the South Atlantic to 371 in the West North Central.

General Summary.

Based upon the information given, it might be conservative to say that in the smaller towns and cities the maximum daily consumption should not exceed about 200 or 210 per cent. of the average, and the hourly consumption should not be greater than about 300 per cent. of the average.

In cities of 100 000 population or more, the maximum daily consumption will generally not exceed about 160 per cent. of the average; and the hourly maximum consumption will be about 235 per cent. of the average.

There are, however, so many factors entering into the matter, that it seems to the author that the data given, instead of furnishing arbitrary figures for the bases of design, indicate strongly the need for a sound study of local conditions in every case. Character of population, living standards, use of the public supply for irrigation or lawn watering, and, perhaps above all, the character of the technical supervision available for operation of the water facilities of the community, need most careful consideration.

How various factors may affect the maximum consumption is indicated by some of the explanations given by various cities. Of twelve cities whose maximum rates seemed to be excessive, 9 attributed them to sprinkling lawns and gardens during unusually dry weather, while the other three named swimming pools on large private summer estates, sewer flushing, and a large fire, respectively. Of 5 whose maximum rates were well below the average, 3 attributed this to the fact that a large part of the consumption was by industries whose consumption rate was uniform; while high

wastage, and the fact that there were few lawns and sprinkling was confined to a few hours per day, were the reasons assigned by the other two.

In addition to the information herein summarized, we hope to check directly with the water-works superintendents figures that depart farthest from the average, and eventually also to check the percentage of services metered against these figures and see what comes from that. In gathering this final information, we shall be obliged to lean upon water-works men heavily for aid, and we hope that they will be able to find the time to help us in this work.

THE QUALITY OF IMPOUNDED WATER SUPPLIES.

BY HARRISON P. EDDY.*

[*Read September 30, 1938.*]

Introduction. In the Northeastern United States the water supplies of many cities and towns are derived from natural lakes or impounding reservoirs. Unlike the practice prevailing in the Middle West there are comparatively few supplies taken directly from the larger streams. For many years the sanitary hazards involved in the use of water supplies from sewage-polluted streams was recognized, and the wise policy of developing impounded supplies from relatively pure upland sources has been favored. In Massachusetts at the present time there is but one city — Lawrence — deriving its supply from a grossly polluted river, the supply being filtered and chlorinated. With the practically inexhaustible Connecticut River flowing between New Hampshire and Vermont and thence through Massachusetts and Connecticut not one municipal supply is taken directly therefrom. In New York one municipality after another has abandoned the Hudson River as a source of water supply in favor of upland sources. In Maine a few supplies are taken from the larger rivers, but only a few. New York City and Boston are notable examples of cities which have gone far afield in order to procure clean upland supplies.

To assure continuously adequate supplies from these upland sources it has been necessary to build large storage reservoirs. It is not always possible to predict with accuracy the probable quality of the waters to be obtained from such impounding reservoirs, as is the case with supplies from existing natural lakes. Numerous papers have already been given before this Association, relating to the various factors affecting the quality of impounded supplies. Generally these papers have dealt with single phases of the problem, as instanced by the numerous and excellent papers dealing with the phenomena relating to the color of stored waters. The present paper, therefore, is an attempt to summarize rather concisely all of the more important factors and conditions affecting the quality of impounded waters and to point out measures whereby unsatisfactory qualities may be prevented or, when they occur, corrected.

Location of Reservoirs. There is a good deal of truth in the old Presbyterian doctrine of predestination, not only as regards the future of human souls, but also as regards the quality of impounded waters. Early decisions relative to the selection of the location of a reservoir determine in large measure the quality of water eventually obtained therefrom. Many factors connected with the catchment area and with the actual reservoir site

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have direct and indirect bearing upon the character of the water to be obtained from the completed reservoir.

Obviously the population upon the watershed is a primary factor, as regards pollution. Distribution of this population upon the watershed, with respect to proximity to streams, the density of the population and whether it inhabits sewered municipalities or scattered farm houses, must be taken into consideration. Industrial developments and the character of the wastes that may be discharged by industries, are particularly significant.

Generally speaking, it is advisable to develop impounded supplies upon streams draining watersheds relatively free from human habitations and industrial developments. Otherwise serious pollution and even infection of the reservoir waters may be anticipated.

In the matter of such characteristics as hardness, color and microörganisms the physical and geological conditions of the watershed and reservoir site are important. Waters from streams in limestone regions will produce a hard water. Sometimes a municipality has a choice of two reservoir sites, one in a limestone region and the other in a noncalcareous region. Other things being equal, it is advisable to go to the noncalcareous area. An interesting example of a municipality having a water supply derived from two main sources, one from a calcareous and the other from a noncalcareous region, is that of the city of Utica, New York. The water supply from the Hinckley Reservoir north of the city is soft, and that from the impounding reservoirs south of the city is hard. In New England most of our impounded supplies are low in hardness, due to the noncalcareous character of our soils.

The topography of the watershed also determines to some extent the color of the supply. Watersheds containing relatively large areas of swamp will yield waters of higher color than drainage areas free from any considerable amount of swampland. On the other hand hilly drainage areas, relatively free from forest and more or less devoted to agriculture, will give waters high in turbidity at times of heavy rainfall.

The distribution of rainfall and its intensity, coupled with other factors, has considerable influence upon the character of the water obtained. Heavy rainfalls may result in very serious conditions of turbidity and pollution. At times of melting snow much surface wash high in polluting matter will enter streams and reservoirs. Occasionally tributary streams entering reservoirs are so located that with heavy run-off, currents induced by such tributaries may bring about short-circuiting through the reservoirs and rapid transit of the pollution and objectionable physical qualities directly to the water-supply intakes.

Drought may so increase the proportion of ground water to surface water in storage that stimulation of algæ growths may occur. This is particularly likely to happen if many days of sunshine prevail.

The topography at the reservoir site itself often determines the quality of the impounded water. If the topography of the site is such that

large areas of the reservoir consist of shallow flowage, stimulation of aquatic growths will occur and the development of algæ and other microorganisms will be fostered. Such growths may, therefore, result in seriously objectionable conditions with respect to tastes and odors. The most satisfactory reservoirs are those with steep slopes and small areas of shallow flowage. The character of the soil comprising the shores of the reservoir is also a factor to be considered, inasmuch as shores of clayey material, when acted upon by the waves, tend to increase materially the turbidity of the stored supply, whereas shores of sand or rock have little effect upon the character of the supply. The shape of the reservoir and the direction of its major axis with respect to prevailing winds determine to some degree the rapidity with which pollution may travel from the point of entry into the reservoir to the intake works. Long narrow reservoirs with their axes coinciding in direction with that of the prevailing winds offer particularly favorable conditions for the travel of pollution from one end to the other. The relation of wind-induced currents to the passage of infectious material from one end of Owasco Lake to the other at Auburn, New York, has been well described by J. Walter Ackerman.

Occasionally a reservoir is built over a swampy area, and although high color in the stored water may result during the early years, this color decreases in time. This is illustrated by the Fells reservoirs of the Winchester water works in which the color of the impounded water has gradually become less during the years the reservoirs have been in service. Such improvement does not always occur. At the No Town Reservoir of Leominster, old accumulations of organic matter have been thought to exert an unfavorable influence upon the quality of the water.

The size of a reservoir with respect to the yield of the drainage area is a factor of some importance as regards growths of microörganisms according to Robert Spurr Weston. The large reservoirs with storage capacity of a year's run-off or better, show on the average lower counts for microorganisms than do the relatively small reservoirs.

Preparation of Reservoir Sites. The water from reservoirs, both old and new, may have unsatisfactory characteristics of one kind or another, among which are the following:— Objectionable tastes and odors due to microörganisms or decomposing organic matter; corrosiveness due to carbon dioxide; excess quantities of iron and manganese; and high color. Experience indicates that such difficulties and objectionable characteristics are more likely to be met with in the case of new reservoirs than in that of old reservoirs, although this is not always so and exceptions frequently occur. The Scituate Reservoir of the Providence supply illustrates difficulties which may occur with the water from a newly constructed reservoir. During the first year that the reservoir was in use a very heavy growth of *Anabæna* occurred. A year ago the reservoir water developed a high manganese content and much difficulty was at first encountered in modifying the treatment processes in such a way as to bring about adequate re-

moval of the manganese. Similar experiences have occurred with new reservoirs at many places.

That old reservoirs are not immune from troubles is illustrated by the development of seriously objectionable tastes and odors due to microorganisms last winter in the water from the Spot Pond Reservoir of the Boston Metropolitan District. This experience has been described in detail to this Association by Samuel E. Killam.

Years ago the engineers and chemists of the Boston Water Works and of the Massachusetts State Board of Health carried on careful and exhaustive studies looking towards the measures for correcting unsatisfactory qualities then existing in the Boston supply. The outstanding development of these studies was the policy inaugurated by the late Desmond FitzGerald of thoroughly stripping the sites of new reservoirs. A noteworthy example of the thorough stripping of a reservoir site is that of the Wachusett Reservoir, constructed approximately 30 years ago.

On the other hand, it was felt by many engineers that the cost of such thorough stripping as was practiced in the case of the Wachusett Reservoir was not justified by the results obtained, particularly as in their opinion the money expended for this purpose might better be spent for adequate filtration works. Furthermore, experience having indicated that after 10 or 15 years the water from a new reservoir would be of about the same quality whether the reservoir site was stripped or not, it seemed to these engineers that the better quality of water for so short a period of time was hardly an adequate reason for the very large expenditure involved in stripping.

Considerations such as these led George W. Fuller and the late Allen Hazen to advise the city of New York against the stripping of the Ashokan Reservoir at the time it was constructed about 20 years ago. It must be noted, however, that this advice of Messrs. Hazen and Fuller was based upon the assumption that filtration of the New York supply would be put into effect. As a matter of fact, plans for adequate filtration works were actually drawn up, although the filters have not been constructed as yet. It is interesting to note, however, in connection with the New York supply, that over the period of time that the Ashokan Reservoir has been in service nearly every form of water treatment known has been utilized, with the exception of actual passage of the water through beds of sand. These treatments have included chlorination, copper sulphate treatment, superchlorination and dechlorination, aëration and even coagulation with alum.

In spite of the generally accepted present-day policy of not thoroughly stripping reservoir sites, a certain degree of site preparation is usually carried out. It is more or less common practice to limit the work of site preparation to the removal of trees and brush and to the grubbing of a marginal strip above and below the high-water flow line. The treatment of the marginal strip by grubbing, prevents the growth of large aquatic plants and provides a reservoir margin much more attractive in appearance

than one heavily grown up with weeds and bushes. Furthermore, such marginal clearing avoids the exposure of large areas of organic mud at times of low water. While the direct effect upon the character of the reservoir water is probably not very great, such effect as is produced undoubtedly is in the right direction.

The advantage of stripping lies in the fact that a clean basin for the storage of the water is provided immediately, even though after a time, due to the deposition of suspended matter, more or less organic in content, a carpet of organic mud is created over the bottom of the once clean basin. It is true also that the products of the decomposition of organic matter will occur to some extent in the case of stripped reservoirs. It is probably correct to state that the quantity of such products will be much less than in the case of unstripped reservoirs.

The waters stored in stripped reservoirs are likely to contain less food material for microörganisms than in the case of unstripped reservoirs. Although freedom from the growth of microörganisms cannot be assured in the case of stripped reservoirs, it is very likely that such growths will be materially less on the average than in unstripped reservoirs.

Often the reservoir site contains appreciable areas of swamp in which the depth of swamp muck is too great to permit easy removal. In such cases it is desirable to cover such deposits with clean sand and gravel.

Of course, from the sanitary viewpoint, it is essential to remove and destroy all habitations upon the reservoir site. Barnyards should be cleaned, manure piles removed, and the site made as clean as possible. All these measures affect advantageously the quality of the supply, likely to be obtained from the new reservoir, from the standpoint of both physical quality and sanitary quality.

Watershed Control. Much may be accomplished in controlling the sanitary quality of impounded water supplies by removing or correcting sources of pollution upon the watershed. It is of particular value to remove habitations and accompanying outbuildings from the marginal areas of reservoirs and from close proximity to tributary streams. In the case of the proposed development of Honeoye Lake for an additional water supply for Rochester, New York, the city plans to purchase a marginal strip of substantial width around the entire reservoir, a perimetal distance of approximately 58 miles. Similar extensive control of watershed areas occurs in the recently developed Wanaque supply of northern New Jersey, and in many of our New England supplies. A few data relative to ownership of watersheds are given in the accompanying table.

Ownership of watershed lands serves also as a means of conserving the physical and esthetic quality of impounded waters. When watersheds are privately owned and devoted to agriculture, heavy rainfall upon and run-off from plowed lands usually increase the turbidity of the reservoir waters and bring into the reservoir organic matter of more or less objectionable nature. Ownership of the catchment area, or of strategically

AREAS OF WATERSHED LAND OWNED BY VARIOUS MUNICIPALITIES AND WATER COMPANIES.

	Area of lake or reservoir.	Total area of watershed.	AREA OF LAND ON WATERSHED OWNED BY MUNICIPALITY OR WATER COMPANY.		SOURCE OF INFORMATION.
	(Acres.)	(Acres.)	(Acres.)	(%)*	
Adams, Mass., Bassett Brook	.....	1 662	1 662†	100.	Massachusetts Department of Health, 1924
Andover, Mass.	221	1 729	31	1.79	Massachusetts Department of Public Health, 1924
Boston, Mass.:					
Lake Cochituate	.....	11 240	296	2.63	Metropolitan District Commission, 1927
Wachusett Reservoir	4 178.7	69 600	4 893	7.02	
Cambridge, Mass., Hobbs Brook and Stony Brook	.....	15 110	618	4.09	Cambridge Water Department, 1927
Fall River, Mass., North Watuppa Lake	.....	4 060	3 040†	75.	Fall River Reservoir Commission, 1927
Fall River, New Bedford and Taunton (Joint Rights)	5 760	32 000	656	2.05	Water Department of the 3 cities, 1927
Hackensack Water Co., N. J.	.....	73 000	1 400	1.92	North Jersey District Water Supply Commission, 1925
Johnstown, N. Y. Main Supply	.....	1 952	1 200	61.4	New York State Department of Health, 1914
Newark, N. J., Pequannock River	.....	40 400	27 500	68.1	North Jersey District Water Supply Commission, 1925
New Bedford, Mass., Quittacas Ponds	.....	7 680	1 800	23.4	New Bedford Water Department
New York, N. Y.:					
Ashokan Reservoir	8 180	164 600	7 042	4.27	Jour. Am. Water Works Assn.
Schoharie Reservoir	1 145	201 000	1 227	.61	Sept., 1923
Kensico Reservoir	2 218	14 100	2 282	16.17	
North Jersey Water District, Wanaque Supply	2 430	60 500	3 780	6.25	North Jersey District Water Supply Commission, 1925
Port Jervis, N. Y., Main Supply	.....	3 520	1 800	51.2	New York State Department of Health, 1920
Providence, R. I., Scituate Reservoir	3 600	59 400	11 400	19.2	Jour. N. E. Water Works Assoc., Sept., 1922
Saranac Lake, N. Y.	224	1 780	44 by village, rest by state	2.47	New York State Department of Health, 1921
Springfield, Mass., Little River Supply	.....	31 100	8 422	27.1	Springfield Water Works
Worcester, Mass., Several Streams	1 034	14 400	2 706	18.8	Worcester Water Department

*% of total area of watershed.
†Includes area of reservoir.

located portions of the area, makes it possible to plant such areas to trees, thereby greatly reducing the harmful effects of heavy run-off upon the quality of the water in the reservoir. As far as the quality of the water is concerned, evergreens are superior to deciduous trees for such planting, inasmuch as less color is leached from the foliage shed by evergreens than from that of deciduous trees and because leaves do not blow into the water. Planting catchment areas to trees is also advantageous as a means of retarding the run-off from torrential rains and equalizing flows.

On many New England watersheds there are considerable areas of swamps from which highly colored water leaches into the streams tributary to impounding reservoirs. Such swamp water increases the color of the supply, and at times growths of microörganisms starting in swamps may seed the entire reservoir. Ditching and drainage of these swamps and, in some cases diversion, assists in preventing increased color therefrom.

In the case of some of the reservoirs of the Boston Metropolitan District where municipalities are located upon the drainage areas, the sewage is intercepted and discharged to treatment plants off the watershed. This is done at Marlborough on the area tributary to the Sudbury reservoir. Furthermore, sand filters for storm water run-off from towns are also employed as at Natick and Marlborough.

Control of sanitary quality can be obtained to some extent by the enforcement of rules and regulations promulgated by the state health department. Such regulations usually prohibit direct acts of pollution and set limiting distances at which sources of pollution may be located with respect to reservoirs and streams. Strict enforcement of such regulations is often difficult, but it is probably true that they have at least an important moral effect upon the inhabitants of water-supply catchment areas. For such regulations to be reasonably effective it is generally desirable in the case of water supplies of the larger cities, such as Boston and New York, to maintain sanitary policing of the reservoirs and drainage areas. Posting is also helpful.

Effect of Storage on Quality. For many years it has been known that long storage has a beneficial effect upon the quality of the water. The first and most apparent effect of storage is the removal of matters carried in suspension and the consequent clarification of the water. Another effect of storage is the reduction of color, brought about by the bleaching effect of sunlight and the coagulation and settling out of the colloidal color. Odors and tastes from industrial pollution are also reduced by storage although not always eliminated. From the standpoint of public health the most important function of storage is the destruction of bacteria, particularly of pathogenic organisms. It is pretty well recognized that a storage period of one or two months serves to render a water practically free from typhoid bacilli should such organisms have been present originally.

The extent to which storage is a benefit is dependent upon several factors of which the actual storage period is the most important. The

primary function of a storage reservoir is to provide a reserve supply to make up the deficiency between yield and consumption during dry periods. Consequently the actual time of storage in any given reservoir may vary widely depending upon the time of year and upon the rainfall. At the end of a dry period a reservoir may be drawn down so low as to provide practically no detention period when heavy rains break the drought. Furthermore, as already referred to, short-circuiting may occur, due to currents set up by tributary streams or by wind action.

At times of spring and fall overturns stored waters may become somewhat unsatisfactory, due to the stirring up of bottom sediments. This stirring increases color, turbidity and corrosiveness and may encourage growths of organisms.

Sometimes long storage has drawbacks. For example, the London supply, derived largely from the polluted Thames, and stored in very large reservoirs, is prone to develop heavy growths of microscopic organisms which interfere with subsequent purification processes.

Reservoir Operation. The quality of the supply taken from an impounding reservoir depends in some measure upon the point of intake. Generally speaking, neither the bottom nor top waters should be drawn. The top waters are more likely to develop algæ growths and the bottom waters are usually colored and may be high in iron and manganese. Furthermore, such bottom waters frequently contain the products of decomposition of organic matter, including carbon dioxide, thereby tending to be more corrosive than waters in the upper strata. As a rule, it is advisable to provide intake ports at different depths, in order that the point of taking may be changed so as to draw the best water. In the case of impounded water subsequently treated in filter plants it has been suggested by Pirnie, based upon the experience of Providence, that bottom water containing natural coagulation substances might be drawn and with proper chemical treatment produce a wholly satisfactory supply and one cooler than if drawn from the upper portion of the reservoir.

Many impounded supplies, of course, are used without filtration. Some control of the quality of the water drawn directly from reservoirs may be obtained by precautions in reservoir operation. Changing the depth of drawing as water levels fall has been mentioned. Drawing off and wasting inferior bottom water at times of spillway overflow tends to improve the general quality of the stored supply. Copper sulphate treatment for algæ control is a well recognized and efficient method for preventing or minimizing undue tastes and odors. The recent developments in the use of activated carbon point to the possibility of using this material for reducing color and odor by direct application to reservoirs. Already this method has been tried out on a small reservoir with reported success, but it is probably too early to draw definite conclusions as to its general adaptability for reservoir treatment. Another possible future development for control

of tastes and odors in moderate capacity distribution reservoirs is the use of chlorine-ammonia treatment.

Water Purification. While much may be accomplished in the way of producing a water of good quality by proper precautions with respect to the location of reservoirs, the treatment of their sites, water shed control and reservoir operation, in many instances, such measures are inadequate. As a matter of insurance against possible infection surviving the storage period, it is generally advisable to chlorinate stored surface waters. Opportunities for chance pollution and even infection in these days of extremely mobile population, due to the widespread use of automobiles, are such that it is unwise to rely wholly upon storage as a protective measure. Chlorination is usually relatively inexpensive and easy to operate. In fact, its very simplicity often leads to the neglect of the limited but essential supervision.

Ordinary chlorination does little to improve the physical character of an impounded supply. In some instances, it actually increases objectionable tastes and odors and furthermore an overdose of chlorine may produce tastes due to chlorine itself. Where intervening storage or filtration is available, chlorine ammonia treatment may be used both to secure disinfection and to reduce tastes and odors. Super-chlorination followed by dechlorination is also effective under some circumstances. Treatment with permanganate of potash is another possible method for taste and odor control but has been used in but a few cases.

One of the oldest methods of reduction of tastes and odors from stored supplies is that of aëration. Aëration is also of value in reducing the corrosiveness of a stored water when such corrosive quality is due to dissolved carbon dioxide. Aëration may be used alone or in conjunction with filtration or chemical treatment.

The application of soda ash or lime to the water as it leaves the reservoir is another way by which the corrosive quality of the water may be reduced. Lime is generally somewhat more effective than soda ash but has the disadvantage of increasing the hardness of the supply.

On the whole, filtration in conjunction with chlorination, chlorine-ammonia treatment or activated carbon affords the greatest assurance of satisfactory quality. There are few supplies even from large impounding reservoirs which cannot be improved by treatment in properly designed and operated filter plants. Such plants give greater assurance of water of uniform excellence than any other method of treatment.

It must not be forgotten that distribution reservoirs for filtered or otherwise treated waters should be covered in order to prevent algæ growths as well as to prevent possible pollution.

Laboratory Supervision. In view of the exacting demands of the public for water not only safe to health but also of pleasing physical properties, the operation of a water supply requires careful check of water quality by regular analyses. The need for such laboratory control is well recognized

where filtration plants are installed, but is less well appreciated in the case of unfiltered impounded supplies. Experience has indicated, however, that regular microscopical examinations of stored surface supplies give warning of increasing numbers of microörganisms. If such warnings are heeded, copper sulphate treatment, for example, can be applied in sufficient time to forestall the excessive development of the organisms and thereby prevent the production of an unpleasant taste and odor. In some instances, stored waters are given corrective treatment with lime or soda ash in which case laboratory supervision of the treatment permits the most economical use of the chemicals consistent with obtaining a non-corrosive water. In the case of many of the larger impounded water supplies in the country, such as the supplies of Northern New Jersey, New York City and Boston, regular analyses of the reservoir waters are carried out by the departments in charge of these supplies.

Progressive water departments, acting in conformity with the information furnished by laboratory findings, can accomplish much in the way of protecting and improving the quality of impounded supplies.

PROCEEDINGS.

FIFTY-FIRST ANNUAL CONVENTION.

SPRINGFIELD, MASSACHUSETTS.

September 27 to 30, 1932.

The following is a synopsis of such parts of the proceedings of the Fifty-first Convention as appear to be of value for the record.

The Fifty-first Annual Convention of the NEW ENGLAND WATER WORKS ASSOCIATION was held at Springfield, Mass., September 27 to 30, 1932.

The technical sessions of the convention were held in the ballroom of the Hotel Kimball, and the exhibits of the Associates were arranged in the main dining room and lobby.

President George C. Brehm presided at the meetings.

TUESDAY, SEPTEMBER 27.

Morning Session.

THE PRESIDENT. It is not only my privilege but my pleasure to declare the Fifty-First Annual Convention of the NEW ENGLAND WATER WORKS ASSOCIATION open.

During these troublesome times the chief executives of our cities are devoting themselves to finding some constructive work for the army of unemployed. They have hardly a minute to give to their families, much less to make speeches of welcome. Nevertheless the Mayor of Springfield has consented to give us a few minutes of his valuable time to welcome the delegates to this convention. It gives me a great deal of pleasure to present to you the Honorable Dwight R. Winter, Mayor of the City of Springfield. (*Applause.*)

REMARKS BY HONORABLE DWIGHT R. WINTER, MAYOR OF SPRINGFIELD.

MAYOR WINTER. Mr. President and members of the NEW ENGLAND WATER WORKS ASSOCIATION:

We can, this year, show you our new, and for the size of Springfield, large water works now nearing completion. I think I can almost say that the bond issue is almost as large as the water-supply itself. We in Springfield are extremely pleased that your organization saw fit and deemed it wise to come to our city this year as this project is approaching completion, because we really feel that we have something here which is worth seeing,

something perhaps somewhat unique in communities of our size. When it becomes a paying proposition we are going to be pleased with it.

I want to greet you not only on behalf of those of us connected with the water system of Springfield, but on behalf of the entire population, and I trust that you will enjoy your stay in our city, that you will find it worth while to such an extent, and will find our hospitality to be so genuine, that you will want to come back to Springfield in a few years and meet with us again. (*Applause.*)

THE PRESIDENT. We are also privileged this morning in having with us Mr. James J. Shea, Water Commissioner of the City of Springfield.

REMARKS BY MR. JAMES J. SHEA, WATER COMMISSIONER.

MR. SHEA. Mr. Chairman, his Honor the Mayor, members of the NEW ENGLAND WATER WORKS ASSOCIATION: It gives me great pleasure, and I regard it as an honor to be here this morning and greet you members of the NEW ENGLAND WATER WORKS ASSOCIATION.

It seems particularly fitting and proper that you should have selected the City of Springfield this year for your annual convention. I do not know of any city of the size of Springfield in the United States which could offer so much to you as we can at the present time from an engineering standpoint. We have, first, the Cobble Mountain development, which contains perhaps the largest earth dam of its type, in the United States; secondly, we have the hydroelectric development, capable of developing 23 000 kw., in connection with the Cobble Mountain development; thirdly, we have the large reservoir recently completed at Cobble Mountain, capable of holding about 23 000 000 000 gallons of water. These in themselves should offer enough attractions to keep you busy during your brief stay in Springfield.

In closing, I am going to reiterate what his Honor the Mayor has said, that we hope that your brief stay in Springfield will be not only of educational value but also of pleasure. (*Applause.*)

ADMINISTRATIVE REPORTS.

The Annual Reports of the Secretary, Treasurer and Editor were submitted by Frank J. Gifford, Albert L. Sawyer, and Gordon M. Fair, respectively. (See page 418.)

The Report of the Finance Committee was read by the Treasurer. (See p. 427.)

Upon motion from the floor, duly seconded, it was voted to accept these reports and place them on file.

PROGRESS REPORTS OF TECHNICAL COMMITTEES.

Brief progress reports of technical committees of the Association were made as follows:

Committee on Specifications for Cast Iron Pipe and Special Castings, by William R. Conard.

Committee to Revise Present Form of Summary Statistics, by Samuel E. Killam.

Committee on a System of Sanitary Scoring of Water Supplies, by E. Sherman Chase.

Committee on Disinfection of Water Mains, by E. Sherman Chase.

Committee on Tests of the Bureau of Standards, by Harry W. Clark.

Committee on Standardization of Pipe Flanges and Fittings, by William R. Conard.

Committee on Educational Service, by Gordon M. Fair.

Award of Dexter Brackett Memorial Medal.

The President. The Dexter Brackett Memorial Medal has been awarded by this Association since 1916 to perpetuate the memory of Dexter Brackett, who was president of this Association from 1889 to 1890. The intent of this medal was that it be awarded to the paper, among all papers published in the Journal during the year, which would best advance water works knowledge.

Your committee, consisting of Harry W. Clark, Chairman, Stephen H. Taylor, and Robert A. Cairns, recommended, and the Executive Committee have approved their recommendation, that the medal this year be awarded to Thaddeus Merriman for his paper entitled, "The Law of Interstate Waters and Its Application to the Case of the Delaware River," published in the September, 1931, Journal.

I am going to ask Mr. J. Waldo Smith if he will not escort Mr. Merriman to the platform and make the presentation.

(*Mr. Smith escorts Mr. Merriman to the platform.*)

Mr. J. Waldo Smith. Mr. President, I have a few words to say regarding the paper entitled "The Law of Interstate Waters and Its Application in the Case of the Delaware River," by Mr. Thaddeus Merriman.

Mr. Merriman's practical mind has produced an extraordinary paper dealing with the law of interstate waters. Nothing approaching it can be found in the technical literature in this country. Some of Mr. Merriman's warm friends have known for a long time that he was a student of legal principles. In pursuing this study he has marshaled all the information available, he has toiled early and late to produce a more perfect whole and to be in a position to assist in that great controversy between New York and New Jersey regarding water. He has been complimented by the corporation counsel of the largest municipal law office in the world, who said, "Where would I be if I did not have this man to tell me what to do?" I am sure that this paper will be studied by all people interested in

the subject, and I know that Mr. Merriman worked very hard to produce it.

It is a pleasure and a privilege, Mr. Merriman, to hand you the Dexter Brackett Memorial Medal, which I hope you will preserve and hand down to your children and grandchildren. (*Applause.*)

MR. THADDEUS MERRIMAN. Mr. Smith, Mr. President, gentlemen of the Association: I am deeply sensitive and conscious of the honor which has been conferred upon me. Little did I think a year ago when I presented the paper at Boston that I should be called upon to be here and find myself in this position.

I am happy to receive this medal because it was my fortune to have known Dexter Brackett, to have known the manner and style of his work, the efforts that he always put into everything that he did, the conscientiousness which he brought to every task. But there is a measure of compensation in receiving this medal because I like to think of it in terms of an acknowledgement that I have at least discharged a portion of my responsibility to the Association. We are all of us indebted to the writers of the papers which appear in the JOURNAL. That after all is the main thing which the Association does and leaves behind it as a matter of permanent record.

I discovered also this morning another compensation which I had never thought of before. The report of your Editor stated that the cost of publication of the JOURNAL this last year had been somewhat less than in the years past because of the fact that some of the papers, at least, had not been illustrated. That was the case with mine, because I do not know how the law can be illustrated in terms of diagrams.

In any event, gentlemen, I am very happy to receive this medal, and I feel a deep debt of gratitude to the committee which did so much work in looking over all the papers. There may have been some work in connection with the preparation of mine, but the committee had an even more difficult task.

I thank you, Mr. President. (*Applause.*)

CLOSING OF POLLS.

THE PRESIDENT. Under the Constitution the President is required, one hour after the opening of the convention, to declare the polls closed. I now do so.

The President is also required to appoint a committee of three tellers to count the ballots.

(The President later appointed Arthur C. King, H. T. Gidley, and G. E. Hawkins as a committee to act as tellers of election.)

TUESDAY, SEPTEMBER 27.

Afternoon Session.

A paper "Description of the Springfield Water Works" was read by Elbert E. Lochridge, Chief Engineer.

THE PRESIDENT. I am going to ask Mr. Elbert E. Lochridge, Chief Engineer, Springfield Water Works, to take the Chair for the remainder of the afternoon session.

The following papers were read: "The Construction of the Cobble Mountain Dam" by Harry H. Hatch, Division Engineer; "The West Parish Filtration Plant" by Herbert F. Salmond, Chemist; "The Cobble Mountain Power Development," by Herbert A. Moody, Hydraulic Engineer, Turners Falls Power & Electric Company.

These papers were discussed by H. K. Barrows, Robert Spurr Weston, E. Sherman Chase, and James Kerslake.

Through the courtesy of the Water Works Manufacturers' Association a reception and dance for members and their guests was held in the evening at the Hotel Kimball.

WEDNESDAY, SEPTEMBER 28.

SUPERINTENDENTS' DAY.

Morning Session.

THE PRESIDENT. The Finance Committee has recommended a budget for the fiscal year ending August 31, 1933, of $11 800. The Executive Committee has voted to recommend its adoption. It now comes before the Association for its approval. What is your pleasure?

On motion of Mr. William R. Conard, duly seconded by Mr. Stephen H. Taylor, it was VOTED that the recommendation of the Finance Committee, approved by the Executive Committee, be adopted.

Oren E. Parks presided during the discussion of the following general topic: Meters, Water Main Cleaning and Water Consumption.

A paper "Domestic Flow as Affecting Meter Registration and Water Revenue," prepared by Harold W. Griswold, Deputy Manager, and W. A. Gentner, Office Engineer, Water Bureau, Hartford, Conn., was read by Mr. Gentner. Messrs. Reeves J. Newsom, R. K. Blanchard (of Neptune Meter Company), J. Herman Smith (of Hersey Manufacturing Company), Charles W. Sherman, J. Walter Ackerman, David A. Heffernan, David E. Moulton, George F. Merrill, Hermann Rosentreter, Henry T. Gidley, Roger W. Esty and Francis H. Kingsbury took part in the discussion.

A paper "Experiences with Water Main Cleaning," was read by Arthur T. Clark, Division Engineer, Greenwich Water Company, Greenwich,

Conn. Messrs. Charles W. Mowry, Percy S. Wilson, William R. Conard, Timothy W. Good, Samuel H. MacKenzie, W. F. Luby, and S. R. Leonard took part in the discussion.

A paper "Water Consumption in American Cities," was read by A. Prescott Folwell, Editor, Public Works, New York City.

Secretary Gifford announced the election by the Executive Committee of the following new members: Theodore M. Beach, Supt., Water Dept., West Springfield, Mass.; Henry Ibbotson, Jr., Supt., Water Dept., North Tiverton, R. I.; Donald Sorelle, Supt., Water Dept., Acushnet, Mass.; Chester M. Everett (of Fuller & Everett), New York City; Charles E. Miller, Asst. Engineer, Dedham Water Co., Dedham, Mass.; Leo T. Purcell, Analyst Wanaque Laboratory, Wanaque, N. J.; Fred J. Reny, Asst. Treas., Portland Water District, Portland, Me.; Daniel C. Smith, Water Commissioner, Haverhill, Mass.; Harold L. Brigham, Asst. Supt., Water Dept., Marlboro, Mass.

Wednesday, September 28.

Afternoon Session.

Richard H. Ellis, presided during the discussion of the following general topic: Tastes and Odors in Water Supplies.

A paper "Powdered Activated Carbon in Water Purification," was read by F. E. Stuart, Industrial Chemical Sales Company, New York City. Messrs. L. H. Enslow, M. M. Gibbons, Charles R. Cox, James Kerslake, R. G. Yaxley, and Samuel H. MacKenzie took part in the discussion.

A paper "Experiences with Ammonia-Chlorine Treatment of the East Providence, R. I. Water Supply," prepared by James V. Turner, Superintendent, and Charles L. Pool, State Sanitary Engineer, was read by Mr. Turner. Messrs. George E. Willcomb, Warren J. Scott, Stuart K. Knox, L. H. Enslow, R. G. Yaxley, Charles L. Pool, H. S. Hutton, and Gilbert H. Pratt participated in the discussion.

A paper "Aëration in Water Treatment," was read by Herman B. Anderson, Vogt Bros. Manufacturing Company, Louisville, Ky. Messrs. Robert Spurr Weston, R. G. Yaxley, George W. Fuller, and Elwood W. Bean took part in the discussion.

Through the courtesy of the Water Works Manufacturers' Association a dinner dance was given during the evening at the Hotel Kimball for members and their guests.

Thursday, September 29.

An excursion was made to the Springfield Water Works. Luncheon was served at Cobble Mountain. There were no technical sessions on this

day. Through the courtesy of the Water Works Manufacturers' Association a Smoker was given during the evening at the Hotel Kimball for members and their guests.

FRIDAY, SEPTEMBER 30.

Morning Session.

A paper "The Quality of Impounded Water Supplies," prepared by Harrison P. Eddy, Consulting Engineer, Boston, was read by E. Sherman Chase. Messrs. Earl C. Craig, Stephen DeM. Gage, Francis H. Kingsbury, Herbert F. Salmond, and Elwood W. Bean participated in the discussion.

A paper "Manganese in Impounded Water Supplies," prepared by Robert Spurr Weston, Consulting Engineer, Boston, and Attmore E. Griffin, Pompton Plains, N. J., was read by F. Wellington Gilcreas. The discussion was participated in by Messrs. Elwood W. Bean, Warren J. Scott, E. Sherman Chase, George D. Norcom, L. H. Enslow, F. E. Stuart, Herbert F. Salmond, and Earl C. Craig.

A paper "The Mechanical Conditioning of Treated Waters" was read by R. S. Rankin, The Dorr Company, New York, N. Y. This paper was discussed by Messrs. L. H. Enslow, James Kerslake and George D. Norcom.

In re Loans by Reconstruction Finance Corporation.

MR. E. SHERMAN CHASE. Mr. President, one of the matters which is foremost in the minds of most of us at the present time is the battle in which we are now engaged against the economic depression. You are all familiar with the organization of the Reconstruction Finance Corporation. The Executive Committee of the Board of Directors of your Association and the Executive Committee of the Manufactuers' Association have prepared a communication which they recommend to be sent to the Reconstruction Finance Corporation. I have a copy of this communication which I will read to you, and I will offer the motion that it be transmitted to the Reconstruction Finance Corporation as an expression of the sentiment of this Association. The communication reads as follows:

The NEW ENGLAND WATER WORKS ASSOCIATION assembled at its Annual Convention and the Executive Committee of the Water Works Manufacturers' Association, jointly express their grave concern as to the disappointing progress that has been made by the Reconstruction Finance Corporation in making loans for self-liquidating construction and rehabilitation projects in the water-works field.

We are mindful of the difficulties involved in the organization and conduct of this vast undertaking and of the inevitable delays in the preparation and filing of applications for loans. It is not intended, therefore, that this expression be taken as unduly critical of the Corporation for the lack of substantial progress. We urge, however, that every effort be exerted by the Corporation to stimulate and facilitate the granting of loans

to eligible projects and that prospective applicants for such loans use the utmost speed in preparing the engineering and legal data required by the Corporation to expedite its action.

The expressed intent of the Relief and Construction Act is to stimulate public works construction in order to help relieve unemployment and to revive normal trade, thereby making it possible also for communities to extend and modernize their facilities at a time when costs are low and the employment is sadly needed. We urge upon the directors and staff of the Reconstruction Finance Corporation that this intent be kept constantly in mind and that the provisions of the Act be interpreted and applied in this spirit.

In order that a sufficient volume of public works be put in hand to help put men to work and to prevent additional unemployment during the coming winter, it is imperative that a large volume of justifiable projects be approved and put under construction as quickly as possible. Waterworks projects are especially well adapted to the employment of considerable local labor and to meet the requirements of the Relief Act. Prompt and favorable action by the Reconstruction Finance Corporation on loans for such work can be of substantial help in the present emergency. We are confident that the delays of the organization period are now over and that the full power of the Corporation may now be exerted toward the objectives sought in the Act. Broad-visioned, vigorous and immediate action by the Corporation, as well as by the interested communities, can do much to make up for the valuable time that has been lost during the last two months.

After discussion by Warren J. Scott, Thomas H. Wiggin, Percy R. Sanders, F. W. Heusing, Stephen H. Taylor, Harold W. Griswold and E. Sherman Chase, the latter's motion was carried.

Vote of Thanks.

PERCY R. SANDERS. Mr. President, I would like to offer the following resolution and move its adoption:

Resolved that the thanks of the Association be extended to his Honor the Mayor and to the other officials and employees of the City of Springfield, and especially to those of the Municipal Water Works, for the many courtesies they have shown us; and also to the Springfield Chamber of Commerce and the Water Works Manufacturers' Association for their assistance in making this convention so enjoyable and successful.

This motion was carried unanimously.

Report of Tellers of Election.

The Tellers of Election submitted the following report:

Total Ballots Cast	226
Blank	1

President.

RICHARD H. ELLIS	220
BLANK	6

Vice-Presidents.

Term Expiring September 1933
- E. Sherman Chase 224
- Blank 2

Term Expiring September 1934
- Howard M. King 214
- Blank 12

For Directors.

Term Expiring September 1933
- Roger W. Esty 221
- Blank 5

Term Expiring September 1934
- Harry U. Fuller 218
- Blank 8

Term Expiring September 1935
- Warren J. Scott 221
- Blank 5

For Treasurer.

Term Expiring September 1933
- Albert L. Sawyer 221
- Blank 5

(*Signed*) Arthur C. King, *Chairman.*
H. T. Gidley,
G. E. Hawkins.

Under our Constitution the old president holds office until this convention is adjourned. I know, however, that you would like to hear a few words from our next president. (*Applause.*)

President-elect Richard H. Ellis. Gentlemen, at this time I am desirous of expressing to the Association my appreciation of the honor which you have just conferred on me. I am also desirous of having you know that I appreciate fully the responsibilities which accompany the honor. I feel considerably appalled with the task, in view of the advancement that the Association has attained under the leadership of my predecessors, but I assure you that I will give unlimited effort to justify the trust which you have placed in me. I thank you. (*Applause.*)

Presidential Address by Retiring President George C. Brehm.

Agreeable to custom rather than to desire, it is my duty to address you at this annual meeting. Our Constitution in fact requires the retiring President to do so. The framers of our Constitution were fortunately so broadminded that they did not specify just what the address should cover; possibly they realized that the average water-works engineer or superintendent is not a speechmaker. With your kind indulgence I will, therefore, ramble along and do my thinking out loud. Should you become weary of it just cheer yourself up by being thankful you are not in my place.

This past year has undoubtedly been the worst of our so-called depression years. While many industries have either stood still or slid back, we find, however, that the very nature of our industry has forced most of us to carry on. In reviewing the past twelve months we find some water works reducing maintenance costs, it is true, but we know of few which have failed to lay some new extensions or services. To the lasting credit of many mayors and councils, and numerous boards of directors, sizable construction has been carried on in many localities. In return for the humanitarian impulse that prompted such work the owners, whether private or municipal, have received much more in plant assets per dollar expended than for many a year previous. That is well and it may spur others on to expedite work which will be needed within the next few years, but for which there is no valid reason for stepping it ahead.

There is one point which should not be overlooked when speaking on water-works operation during financially troublesome periods. It is the hue and cry of uninformed and politically inclined agitators to reduce expenditures at the wrong end, something like saving at the spigot to waste at the bunghole. Too often we hear of someone in authority over finances attempting to stir up a so-called "reduction of overhead" by eliminating or reducing the very men who through long years of study and experience have gained knowledge of the plants under their charge. When the percentage of annual costs which can be rightly charged to superintendence or engineering is figured, it will be found that the saving by such foolishness is negligible in comparison with the resulting loss to the plant and to its service for years to come.

One or two examples will suffice to show the "penny wise and pound foolish" side of such extremes. In one city the emergency man has been laid off, with never a thought of what expensive damage may result from just one uncontrolled break. Again in another city the watchmen have been so reduced in number that proper patrolling of the watershed and reservoir is impossible. It needs no far stretch of the imagination to see what terrific toll may be taken by an epidemic possible at any moment from pollution of the supply, aside from the loss of many thousands of dollars.

It is unfortunate that in many of our communities officials are attempting to reduce the tax rate by either directly diverting water-earned money, or by "over-training" on the reducing of the departmental forces. In some places, sad to say, the regular men trained by years of service are being laid off so that the unemployed or the welfare men may be kept at something that has the appearance of work.

Of course good construction and proper maintenance are lost sight of in the endeavor to lower the tax rate with the hopes of reëlection. Now, if ever, is the time for every good water-works man to stand his ground in the fight to prevent uneconomical and unwarranted construction which may be promoted by well-meaning people who have only the employment

problem in mind. If the work has had proper engineering investigation and design, then the work is warranted, but in any event it is wise to "investigate before investing."

Another recent political trick which should be stopped is that of charging employees of other departments to the water-works pay rolls. It would be far better to honestly admit a "payless pay day" than to falsify records, not to mention the injustice of diverting the funds paid by water consumers in order to lighten the tax burden.

Our Association, which has worked for a bill to prevent this diverting of funds, should renew its vigor, and likewise I feel there is much work for our committee recently appointed for the purpose of drafting a bill to protect water-works officials from the vicissitudes of political life.

Another committee which has made an important announcement at this convention is the committee on award of the Dexter Brackett medal. The great predominance of engineering titles on the papers leads me to wonder why more of our superintendents do not submit papers based on their own discoveries or on practical problems encountered. Dexter Brackett was himself greatly interested in making our Association a practical one, and while we appreciate the very valuable papers heretofore submitted and join in the voicing of merit on the awards, yet we believe that Dexter Brackett would also have encouraged some contributions from the practical everyday man. Surely we have numerous superintendents with the ability to think clearly and write plainly upon vital topics which will advance water-works knowledge.

My predecessor in his presidential address touched on another vital point, namely, increased membership. Any organization that simply holds its own is really slipping back, and it is imperative that we increase the size, scope and territory of this Association. To my mind the surest way to accomplish this is by means of a fairly large membership committee, well selected geographically throughout New England, and composed of men who might be termed "go-getters." There is no reason why every water company and every water department in New England should not hold membership with us,—in fact, that is the exact purpose for which we were established. The broader our membership the broader our good works will extend. Such a committee might with dignity put in force many schemes for this good work, such as a semi-annual day to be known as "Mayors Day," at which every mayor and every chairman of a board of selectmen would be invited with his superintendent, member or not, to attend a specially arranged program. These meetings could not but help drive home the fact that membership and attendance at our meetings is not only a privilege to become more conversant with water-works practice and better acquainted with the officials of other communities, but truly a duty that every water company or municipal plant owes its owners or consumers, that those in charge be at all times kept up to the minute in the theory and practice of their business.

In closing may I assure you of the pleasure I have enjoyed in this office and the deep appreciation I owe everyone who has assisted me to carry on through the past year. I know that the affairs of the Association are being placed in able hands, and with this I wish my successor well.

THE PRESIDENT. If there is no further business, I declare the Fifty-first Annual Convention of the New England Water Works Association closed.

(*Adjourned.*)

Annual Report of the Secretary.

Mr. President and Gentlemen of the New England Water Works Association,—The Secretary submits herewith the following report of the changes in membership during the past fiscal year, and the general condition of the Association.

The present membership is 809, constituted as follows: 14 Honorary Members, 683 Members, 0 Juniors, 15 Corporate Members and 97 Associate Members. The detailed changes are as follows:

MEMBERSHIP.

September 1, 1931.	Honorary Members	13			
	Elected:				
	September, 1931	1			14
September 1, 1931.	Members, Total		690		
	Withdrawals:				
	Resigned	27			
	Dropped	3			
	Died	16			
	Transferred to Honorary Membership	1	47	643	
	Elected:				
	September, 1931	19			
	November, 1931	8			
	December, 1931	1			
	January, 1932	2			
	February, 1932	1			
	March, 1932	4			
	May, 1932	1			
	June, 1932	3		39	
	Reinstated:				
	Resigned in 1929–30	1		1	683
September 1, 1931.	Juniors, Total		0		
September 1, 1932.	Juniors, Total		0		0
September 1, 1931.	Associates, Total		99		
	Withdrawals:				
	Resigned	9			
	Dropped	3	12	87	
	Elected:				
	September, 1931	7			
	January, 1932	1		8	
	Reinstated:				
	Resigned, 1900	1			
	Resigned, 1912	1		2	97

September 1, 1931.	Corporate Members, Total	14	
	Elected:		
	September	1	15
September 1, 1932.	Total Membership		809
September 1, 1931.	Total Membership		816
	Net Loss		7

Members Elected September 1, 1931 to September 1, 1932.

Honorary Members.

September 16, 1931. Charles W. Sherman. (1)

Members.

September 29, 1931: Daniel A. Cushman, Luther E. Cotton, John E. Landers, Joseph Landers, Harry Manson, Horace R. Nash, William Peterson, Alan L. Pratt, Dana M. Pratt, Benjamin G. Sargent, Oscar J. Scammon, Harold E. Weeks. (12)

October 1, 1931. Patrick J. Barry, Alexander Burnie, Lester A. Bridges, George E. Clapp, Theodore W. Grindle, Birdsell N. McIntyre, Edmund C. Sanderson. (7)

November 18, 1931. Irving B. Crosby, Daniel J. Donovan, Linn H. Enslow, Samuel F. Newkirk, Jr., Chester L. Nyman, Kenneth E. Packard, Everett E. Turkington, Angelo A. Potenza. (8)

December 9, 1931. Winthrop C. Butts. (1)

January 13, 1932. Walter M. Hatch, Thomas H. Stothart. (2)

February 9, 1932. Fred T. Coffin. (1)

March 9, 1932. George N. Buckhout, Donald C. Calderwood, Arthur B. Stiles, Harold E. Watson. (4)

May 11, 1932. E. B. Myott. (1)

June 28, 1932. Frank J. Driscoll, Frederick Ohrt, George Webster. (3)

Reinstated:

Resigned, 1929–1930 (Harry B. Collins). (1)

Associates.

September 29, 1931. Inertol Co., Inc.; Revere Copper and Brass, Inc.; Sentry Mfg. Co. (3)

October 1, 1931. American Active Carbon Corp.; Multi Steel Company, Nelson Cement Stone Co., Inc.; East Jersey Pipe Company. (4)

Reinstated:

Resigned, June 9, 1900 (Jenkins Bros.). (1)

Resigned, January 10, 1912 (Perrin, Seamans & Co., Inc.). (1)

Corporate.

September 29, 1931. Lawrence Water Dept., Mass. (1)

Members.

Resigned: E. A. Barrier, M. N. Baker, G. A. Benjamin, J. D. Capron, G. C. Danforth, G. A. Elliott, E. G. Gillette, Alfred Gildersleeve, A. E. Gorman, G. M. Graffam, L. V. Harper, J. F. A. Leonard, T. W. Lesage, Henry Manley, Wm. B. McCaleb, C. E. McDonald, H. L. Newhall, J. E. Palmer, M. B. Palmer, C. H. Poor, V. B. Siems, W. J. Turnbull, W. D. Van Brunt, F. D. West, C. M. Whitaker, J. M. Whitham, C. W. Whiting. (27)

Dropped: F. L. Andrews, E. L. Haskell, P. J. Barry. (3)

Died: C. B. Beasom, H. W. Clark, J. J. Devlin, O. J. Eagan, G. F. Evans, G. A. King, W. G. Newhall, S. H. Pitcher, Edwin Quinn, J. T. Robertson, E. H. Rogers, G. Z. Smith, W. H. Vaughan, William Wheeler, O. J. Whitney, G. S. Williams. (16)
Transferred to Honorary Membership: Charles W. Sherman. (1)

Associates.

Resigned: Allis Chalmers Mfg. Co.; American Cast Iron Pipe Company; H. W. Clark Company; Hume Pipe of N. E., Inc.; Herbert Kennedy Company, Inc.; Jenkins Bros.; McWane Cast Iron Pipe Co.; National Cast Iron Pipe Company and James E. Williamson. (9)
Dropped: Mansfield Foundry Company; McEverlast, Inc.; Vogt Brothers Mfg. Co. (3)

Receipts for Fiscal Year, September 1, 1931 to September 1, 1932.

Entrance Fees			$188.00
Annual Dues:			
Members	$3 808.14		
Corporate Members	150.00		
Associates	1 955.00	$5 913.14	
Fractional Dues:			
Members	24.00		
Associates	15.00	39.00	
Past Dues:			
Members	72.00		
Associates	40.00	112.00	
1932–1933 Dues:			
Members	9.50	9.50	
Total Dues			6 073.64
Advertisements			3 196.00
Subscriptions			540.86
JOURNALS			84.76
Sundries			1 257.76
Total			$11 341.02
There is due the Association:			
Advertising		$924.00	
Subscriptions		12.00	
Reprints		48.62	
JOURNALS		2.50	
Standard Specifications		.75	
Cuts		6.40	994.27
Total			$12 335.29

Respectfully submitted,

FRANK J. GIFFORD, *Secretary.*

Annual Report of the Treasurer.

September 1, 1931 to August 31, 1932.

The President and Members of the New England Water Works Association:

I herewith submit my report as treasurer for the year ending August 31, 1932.

Receipts.

September 1, 1931—Cash on hand			$1 949.02
Initiation fees	$188.00		
Dues	6 073.64	$6 261.64	
Interest and dividends		694.42	
Journal:			
Advertisements	3 196.00		
Subscriptions	540.86		
Sale of Journals	84.76		
Sale of Reprints	57.20		
Sale of Half Tones	24.01	3 902.83	
Miscellaneous:			
Certificates of membership	21.00		
Standard Specifications	12.75		
Meter sheets	8.63		
B. S. C. E. account June Outing	94.97		
Tuition fees—Water Works School	315.00		
Sundries	29.78	482.13	
Total receipts			$11 341.02
			$13 290.04

Expenditures.

Journal:			
Advertising agent's salary and commission	$113.20		
Editor's salary	500.00		
Editor's expense	42.71		
Plates	142.34		
Printing	3 191.10		
Reporting	423.38		
Reprints	514.91		
Stationery and postage	88.19		
Sundries	8.20	$5 024.03	
Office:			
Engineering Societies of Boston	$2 160.00		
Exchange and check tax	4.76		
Printing, stationery and postage	250.59		
Secretary's salary	400.00		
Secretary's expense	132.25		
Treasurer's salary, bond and expense	117.63		
Sundries	84.88	3 150.11	

Meetings and Committees:			
Annual Convention	$861.40		
Committee on pipe, share of expense	400.00		
Committee on pressure gages	13.60		
Dinners for guests	27.00		
Printing, stationery and postage	667.29		
Stereopticon	30.00		
Water Works School	393.09		
Sundries	6.98	2 399.36	
Total expenditures			$10 573.50
August 31, 1932—Cash on hand			2 716.54
			$13 290.04
Invested Funds.			
Invested Funds, September 1, 1931			$15 807.43
Interest on deposits		$29.18	
Interest on savings bank deposits		665.24	694.42
			$16 501.85
Interest paid over to the Association			694.42
Invested funds, August 31, 1932			15 807.43
			$16 501.85

The Finance Committee for the fiscal year ending August 31, 1932 recommended a budget of $11 800.00.

There has been expended during the year $10 573.50, leaving an unexpended balance of $1 226.50. The details are as follows:

	Journal.	Office.	Meetings.
Appropriation	$7 000.00	$3 200.00	$1 600.00
Transferred from	799.36	....	....
	$6 200.64	$3 200.00	$1 600.00
Transferred to	....	....	799.36
	$6 200.64	$3 200.00	$2 399.36
Expended	5 024.03	3 150.11	2 399.36
Balance	$1 176.61	$49.89	$000.00

The amount received for tuition fees for the Water Works School, as authorized by the Executive Committee was $315.00, and the expenses were $393.09 making the net cost of the experiment to the Association, $78.09.

Respectfully submitted,

Albert L. Sawyer, *Treasurer.*

TREASURER'S REPORT.

STATEMENT OF RECEIPTS AND EXPENDITURES.

Receipts.	
Cash on hand September 1, 1931	$1 949.02
Interest on bonds and deposits	694.42
Received from Secretary	10 646.60
	$13 290.04

Expenditures.	
Bills paid as per vouchers	$10 573.50
Cash on hand August 31, 1932	2 716.54
	$13 290.04

ASSETS AND LIABILITIES.

Assets.		
Cash in banks as per list		$18 523.97
First National Bank	$2 716.54	
City Five Cents Savings Bank	2 000.00	
Farmers and Mechanics Savings Bank	2 068.46	
Franklin Savings Bank	2 000.00	
Haverhill Savings Bank	2 000.00	
Home Savings Bank	1 011.25	
Mechanics Savings Bank	1 261.19	
Pentucket Savings Bank	2 000.00	
Peoples Savings Bank	1 466.53	
Suffolk Savings Bank	2 000.00	
Accounts Receivable		994.27
Advertisements	924.00	
JOURNALS	2.50	
Subscriptions	12.00	
Reprints	48.62	
Cuts	6.40	
Standard Specifications	.75	
		$19 518.24

Liabilities.	
Surplus	$19 518.24
	$19 518.24

Annual Report of the Editor.

To the New England Water Works Association: The Editor submits herewith the following report for the year ending August 31, 1932.

As has been customary in the past, the tables of financial figures, accompanying the report, are based upon total charges and accounts receivable, rather than actual cash received or disbursed.

Table 1 is a statement of the material published.

Table 2 gives the receipts and expenditures for the year.

Table 3 is a comparison of the JOURNAL for the past year with preceding years.

Size. The four issues contained 644 pages, of which 437 were text.

Cost. The gross cost of the JOURNAL was $5 024.03, equivalent to $6.18 per member, and the net cost was $1 121.20, equivalent to $1.38 per member.

Reprints. Fifty reprints of each paper have been furnished to the author where desired.

Circulation. The present circulation of the JOURNAL is:

Members, all grades	809
Subscribers	132
Exchanges	16
Total	957

(JOURNALS *have been sent to all subscribers.*)

Respectfully submitted,

GORDON M. FAIR, *Editor.*

EDITOR'S REPORT.

TABLE 1.

STATEMENT OF MATERIAL IN SEPTEMBER AND DECEMBER, 1931, AND MARCH AND JUNE, 1932, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Date.	Pages of.								
	Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Insert Plates.	Total	Total Cuts.
September, 1931	113	3	116	0	48	5	0	169	3
December, 1931	57	36	93	7	47	5	0	152	6
March, 1932	117	3	120	0	44	5	1	170	17
June, 1932	98	10	108	0	40	5	0	153	20
Total	385	52	437	7	179	20	1	644	46

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF SEPTEMBER AND DECEMBER, 1931, AND MARCH AND JUNE, 1932, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Receipts.		*Expenditures.*	
Advertisements	$3 196.00	Advertising Agent's salary and commission	$113.20
Sale of JOURNALS	84.76	Editor's salary	500.00
Sale of reprints	57.20	Editor's expense	42.71
Subscriptions	540.86	Plates	142.34
Sale of cuts	24.01	Printing	3 191.10
	$3 902.83	Reporting	423.38
		Reprints	514.91
		Stationery and postage	88.19
Net cost of JOURNAL	1 121.20	Sundries	8.20
	$5 024.03		$5 024.03

EDITOR'S REPORT.

TABLE 3.

COMPARISON OF JOURNALS OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXXVI.	FOUR ISSUES FOR FISCAL YEAR ENDING AUG. 31,							
	1922.	1924.	1925.	1926.	1927.	1928.	1929.	1930.	1931.*	1932.
Average edition (copies printed)	1 100	1 100	1 100	1 100	1 100	1 138	1 200	1 350	1 260	1 200
Average membership	826	764	755	775	784	808	831	822	816	813
Circulation at end of year	929	880	873	906	916	955	993	980	955	957
Pages of text	618	404	421	523	492	528	507	570	410	437
Pages of text per 1 000 members	748	529	558	675	628	654	610	693	502	537
Total pages, all kinds	801	611	644	761	724	769	745	812	682	644
Total pages per 1 000 members	970	800	853	982	952	952	896	988	836	790
GROSS COST:										
Total	$6 354.10	$4 783.60	$5 272.91	$6 524.62	$5 839.36	$6 849.44	$6 740.87	$8 054.59	$6 135.33	$5 024.03
Per page	7.93	7.83	8.19	8.57	8.07	8.91	9.06	9.92	9.00	7.80
Per member	7.69	6.26	6.98	8.42	7.45	8.48	8.12	9.80	7.52	6.18
Per member per 1 000 pages	9.60	10.25	10.84	11.07	10.29	11.02	9.77	12.07	9.00	9.62
Per member per 1 000 pages text	12.47	15.50	16.58	16.10	15.13	16.06	16.01	17.19	18.34	14.30
NET COST:										
Total	$2 434.26	$561.51	$943.40	$2 040.28	$710.63	$1 716.25	$1 857.58	$3 664.76	$1 252.21	$1 121.20
Per page	3.04	0.92	1.46	2.68	.98	2.23	2.07	4.51	1.84	1.74
Per member	2.95	0.74	1.25	2.64	.91	2.12	2.24	4.46	1.53	1.38
Per member per 1 000 pages	3.68	1.20	1.94	3.47	1.26	2.76	2.50	5.49	2.24	2.14
Per member per 1 000 pages text	4.77	1.82	2.97	5.05	1.85	4.02	4.41	7.82	3.73	3.16

*Including Comprehensive Index, 1882 to 1930.

REPORT OF FINANCE COMMITTEE.

To the Executive Committee of the
New England Water Works Association.

Gentlemen:

The Finance Committee has examined the books and accounts of the Secretary and the Treasurer for the fiscal year ending August 31, 1932, and finds them correct.

The Committee submits the following budget for the fiscal year ending August 31, 1933:

	Expended. 1931–1932.	Recommended. 1932–1933.
JOURNAL	$5 024.03	$6 500.00
Office	3 150.11	3 200.00
Meetings and Committees	2 399.36	2 100.00
	$10 573.50	$11 800.00

The amount recommended for expenditures the coming year is $11 800.00, the same amount as for this year. Five hundred dollars has been taken from the appropriation from the JOURNAL and added to the appropriation for Committees and Meetings to take care of the expense of the Water Works School.

Your committee would recommend that the accounts of the Association be audited in the future by a certified public accountant under the direction of the Finance Committee.

Respectfully submitted,

(Signed) A. H. O'BRIEN,
S. H. TAYLOR,
Finance Committee.

September 22, 1932.

November Meeting.

Hotel Brunswick, Boston, Mass.

Wednesday, November 9, 1932.

President Richard H. Ellis in the Chair.

Mr. Arthur D. Weston spoke on the work and financial requirements of the Emergency Planning Bureau, an organization for the employment and aid of unemployed engineers and architects in Metropolitan Boston.

Secretary Gifford announced the election by the Executive Committee of the following new member:

Roger G. Oakman, Asst. Supt., Water Department, Needham, Mass.

A paper "The High Speed Diesel Engine as a Prime Mover for Pumping Stations," was read by Elliott Earl, Consulting Engineer, Boston, Mass., formerly Research Assistant, Engineering Experiment Station, Pennsylvania State College, Pennsylvania. Myron S. Huckle, Otto Nonnenbruch, Arthur L. Shaw, and J. Howard Hayes participated in the discussion.

Water Works Construction vs. Welfare Donations.

Remarks by Francis H. Kingsbury, Senior Assistant Engineer, Massachusetts Department of Public Health.

Recently the chairman of a board of water commissioners inquired at the office of the Massachusetts Department of Public Health concerning the use of able bodied men, otherwise dependent upon the Welfare Department, on construction work for the Water Department. As there was some doubt as to the proper method of procedure in these matters, I conferred with Mr. Waddell's office and also with certain town officials who have met this problem in the past, and wish to give you the benefit of my investigations.

Before presenting a solution of the problem it may be well to consider certain legal phases, as outlined to me by Mr. Waddell, the Director of Accounts.

First, the only funds available to the Welfare Department are those appropriated and raised by taxation each year except that under provisions of Chapter 44 of the General Laws money may be borrowed for one year for emergency appropriations approved by a board composed of the Attorney General, the State Treasurer and the Director of Accounts in the Department of Corporations and Taxation.

Second, that the Water Department may expend such sums as may be appropriated for laying and relaying water mains and that the funds may be raised by borrowing for a period from five to twenty-five years dependent upon the size of the pipes to be laid.

A community is responsible that none of its citizens shall suffer from hunger, sickness or cold. If means can be developed whereby the head of a

family may receive work or be required to work instead of receiving a dole, the whole community will benefit. The dispensing of charity through welfare departments to men able to work is almost a total loss to the community. In fact if continued beyond an extreme emergency it may undermine the self-respect and ability of the recipient of aid. Any employment that can be offered to such men by the community is preferable to charity. Certain communities have gone to some length in providing such work. Among them are Framingham, Winchester, Newton, Marblehead, Saugus, Weymouth, Gloucester, Wellesley and Stoneham. Some of the work has dealt with the improvement of park lands and the general beautification of the municipality, and some has been directed toward sewer construction.

Non-revenue producing work afforded to persons who would otherwise be the recipients of charity goes part way in the benefit to the individual furnished employment, and to the municipality, in that it receives a certain return for the money dispensed. However, such appropriations, while they may reduce the amount expended for welfare, must in turn increase the amounts expended for non-productive works. If work can be given on revenue-producing projects, the municipality will benefit financially in the long run.

As you know, there are in every community certain works which the Water Department would like to undertake but which have been delayed for several years. As a matter of common sense it seems that it should be possible under coöperative agreement between the Welfare Department and the Water Department to put able-bodied men now receiving welfare relief to work with the Water Department on such undertakings as the laying of mains to tie up dead ends and other construction work of a similar nature. It is, of course, expected that the present emergencies will be overcome in the not distant future, certainly before the life of the works will have been reached.

After conference with the Director of Accounts and with certain town officials it appears that there is no way in which a town may direct any of its officers to employ welfare labor, and the town may not legally specify the particular way in which the work shall be done except to limit the appropriation so that only those otherwise entitled to aid would be employed. Water Commissioners are undoubtedly amenable to the suggestions of public opinion when such public opinion may be definitely set forth. It has therefore been found advantageous to obtain an expression of opinion at the time the money is appropriated.

The Article for the town warrant should be made in its regular form, and it is advisable to attach thereto the general phrase "or to do any act or thing relating thereto." The regular votes should be passed granting and appropriating the money, and if borrowing is necessary the regular supplementary vote should be passed authorizing such borrowing and defining the life and amount of the bonds or notes in accordance with the legal requirements.

In addition, in order that there may be no doubt as to what is contemplated and in order that there may be an expression of opinion by the townspeople that able-bodied men receiving welfare aid should work for what they get, it is advisable that a vote be passed expressing the sense of the meeting. One such vote, a modification of that adopted in the town of Winchester in September, is as follows:

Voted, that it is the sense of the meeting with respect to the appropriation made under Article...., (refer to above article) made for the purpose of.....;

that while the work authorized is necessary for said purpose, it is undertaken as a measure of relief whereby employment may be given to inhabitants of the town standing in need thereof;

that the work is to be done under the direction of the Water Commissioners, and the Board of Public Welfare is to act in the premises as an investigating committee for the purpose of affording its facilities and experience in conducting the necessary investigations for the ascertainment of the worthiness and need of employment of those who apply to the Water Department therefor and accordingly those employed shall not be considered as having received aid or employment from the Department of Public Welfare;

that the Water Commissioners shall be at full liberty in the exercise of their discretion to use hand labor in doing said work in so far as they shall deem reasonably possible.

This method of procedure provides that the funds will be appropriated to the Water Department. Now it is possible under certain conditions that the Welfare Department may have funds which it would ordinarily dispense for relief but which it may preferably dispense contingent on the requirement that able-bodied men otherwise receiving such relief should perform some work for the benefit received. In the old days of the poor farm and the work-house this was obligatory, and few cash disbursements were made. However, Section 2, Chapter 117 of the General Laws, provides in part as follows:

Section 2. The overseers of the poor, hereafter in this chapter called the overseers, shall have the care and oversight of all such poor and indigent persons so long as they remain at the charge of their respective towns, and shall see that they are suitably relieved, supported and employed, either in the workhouse or almshouse, or in such other manner as the town directs, or otherwise at the discretion of the overseers.

Since most of our less fortunate citizens still retain a large measure of their self respect there should be no great difficulty in persuading able-bodied men that they should work for money received, if work is available. Under such conditions the Welfare Department might adopt the policy of sending men to the Water Department for work on relief projects and of giving them relief from the welfare appropriation in proportion to the work done for the Water Department. This method may be available during the present year and until the next town meetings are held, but it is agreed that it is preferable that appropriations be made directly to the

Water Department and that by coöperative investigation the Water Department and Welfare Department agree as to the men most in need of employment in lieu of charity.

I realize that this subject has so many possibilities for controversy due to local conditions that it is almost impossible to lay down a set rule of procedure for all cases. Suffice it to say that the principle is agreed upon that those in need should be given work, preferably on revenue-producing projects. Where there is a will, the way may be found by coöperative arrangements between the Welfare Department and the Water Department or other departments engaged in public work.

There is a warning which should be sounded in respect to this matter. Attempts will be made to inject politics into the situation, and it is to the interest of the Water Department to avoid political interference. In addition these measures should be considered for adoption for the duration of the emergency only, otherwise the community will foster the growth of a group who will become dependent upon municipal employment, with the result that the city or town will be required to do more and more of this work until a point of extravagance will be reached.

It may be argued by the water consumers that the employing of welfare labor on water-works construction constitutes another indirect tax upon them not shared by all citizens. They must consider, however, that even though this be true they are at least getting something back for that portion of their town tax which would otherwise go for welfare relief.

CHARLES W. SHERMAN.* There is one other point which may be worthy of mention. It seems possible that a number of our towns may have to hold special town meetings before the winter is very far advanced. The welfare funds may be exhausted, and it may become necessary to take some emergency measures. If that should be the case, it might be worth while for our boards of water commissioners to consider whether it would not be well for them to ask for special appropriations, either from their revenues, if those are sufficient, or from the borrowing power which can be invoked, to do some of the work during the winter which ordinarily would be done under more favorable weather conditions. That means loss of efficiency, and not only loss of efficiency, as Mr. Kingsbury has pointed out, from the character of the labor performed, but loss of efficiency in cutting through frost, which would not be necessary if the work was postponed until spring.

There is at least room for consideration of the question as to whether, in the present emergency, communities cannot better afford to spend more money for needed construction in that way, even at the loss of the maximum efficiency of ordinary labor as compared with skilled labor, than to postpone the work until later in the season and leave a larger number of people wholly dependent upon welfare funds.

(*Adjourned.*)

*Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

DECEMBER MEETING.

HOTEL BRUNSWICK, BOSTON, MASS.

Wednesday, December 14, 1932.

President Richard H. Ellis in the Chair.

The Secretary announced the election by the Executive Committee of the following new members:

John Stanley Wise, General Manager of various water companies of Northeastern Public Service Co., Portland, Maine.

James Beecher Swaim, Assistant General Manager, Northeastern Public Service Co., Portland, Maine.

The President announced the death of the following members: Harry C. Kerr, Morris Knowles, J. W. Ledoux, Dr. Henry P. Walcott, Julian P. Wood, John F. Lucey.

MR. ROBERT SPURR WESTON outlined the program of the 1933 water works school.

A paper "The New High Service Water Supply at Concord, N. H.," prepared by Percy R. Sanders, Superintendent Water Works, Concord, N. H., and Frank A. Marston, Consulting Engineer, Boston, Mass., was read by Mr. Marston. The discussion was participated in by Messrs. Herbert C. Crowell, Roger W. Esty, Gordon M. Fair, Robert Spurr Weston, John L. Howard, Francis H. Kingsbury, William G. Starkweather, Reeves J. Newsom, Hervey A. Hanscom, and Henry T. Gidley.

A paper "Reconstruction of the Lebanon, N. H. Water Works," was read by Richard S. Holmgren, Principal Assistant Engineer with H. K. Barrows, Consulting Engineers, Boston, Mass. Messrs. E. Sherman Chase, H. K. Barrows, and S. S. Perry took part in the discussion.

(*Adjourned.*)

MORRIS KNOWLES.

Morris Knowles, Sanitary Engineer and City Planner, died suddenly of a heart attack at his home in Pittsburgh, Pennsylvania, on November 8, 1932. Mr. Knowles had been at his desk in his office the day before his death.

Morris Knowles was born in Lawrence, Mass., October 13, 1869. As a young man, he was a neighbor of Hiram F. Mills, who at that time was conducting, at the Lawrence Experiment Station, the historic studies in water and sewage treatment. In part, at least, as a result of his contacts with Mr. Mills, Mr. Knowles elected to study engineering at the Massachusetts Institute of Technology, whence he was graduated in 1891.

From his early acquaintance and friendship with Mr. Mills and from his upbringing in the atmosphere of sanitary engineering that prevailed at Lawrence at that time, Mr. Knowles went to the practice of his profession under men who were then, or later became, outstanding leaders in the field of sanitary engineering. During his student days, he served an apprenticeship under Richard A. Hale, then principal assistant engineer and later chief engineer of the Essex Company, Lawrence. Upon graduation from M.I.T., Mr. Knowles became assistant engineer for the East Jersey Water Company under Clemens Herschel, chief engineer, and J. Waldo Smith, principal assistant engineer. In 1893, he became assistant engineer of the Massachusetts State Board of Health under F. P. Stearns. Mr. Knowles was personal assistant to Mr. Stearns in the latter's investigation of a water supply for Boston and vicinity, leading to the formation of the Massachusetts Metropolitan Water Board, and the development of the Wachusett Reservoir and Aqueduct to supply Boston and twenty-eight surrounding cities and towns.

At the same time, Mr. Knowles was a member of the Water Board at Lawrence, his home town. This service marked the beginning of an intimate contact with the municipal water supply of Lawrence. This contact was always maintained, the organization which he headed returning there many years later to build additions to the slow sand-filter plant and to report on new sources of supply.

In 1897, Mr. Knowles became Resident Engineer of the Pittsburgh Filtration Commission, and established a laboratory and experimental filters looking to the improvement of the Pittsburgh water supply. Following completion of the report of the Pittsburgh Filtration Commission, and prior to the actual construction of the Pittsburgh filters, Mr. Knowles went to Philadelphia in 1899 to perform a similar service for that city in experimental work on filters and investigation of a proposed new gravity water-supply. In 1900 as assistant engineer to John R. Freeman, Mr.

Knowles assisted in the preparation of the classic report on an additional water supply for the city of New York.

In 1901, Mr. Knowles returned to Pittsburgh and became Chief Engineer of the Pittsburgh Bureau of Filtration. In this capacity he designed and supervised the construction of the slow sand-filters for the city's water supply from the Allegheny River at Aspinwall.

Upon the completion of the Pittsburgh Filtration Plant, Mr. Knowles devoted himself actively to the consulting-engineering practice which he had established in partnership with L. E. Chapin in Pittsburgh a few years before. This practice he continued later as a corporation under his own name and maintained it until his death.

Mr. Knowles was a member of the engineering committee of the Flood Commission of Pittsburgh, which compiled an exhaustive report upon flood protection and prevention. Following the completion of the report in 1911, he continued as a member of the executive committee of the Pittsburgh Flood Commission. He was a member of the Board of Advisory Engineers of the Miami Conservancy District, 1914, and Chief Engineer of the Essex Border Utilities Commission, 1916–1921.

During the war, his organization supervised the construction of Camps Meade and McClellan, and in 1918–1919 he was appointed Chief Engineer of the Housing Division of the United States Shipping Board. He was a member of the Engineering Board of Review of the Chicago Sanitary District in 1924, and became Chairman of its committee on construction program.

Mr. Knowles early sensed the impending participation of the civil engineer in the field of city planning and zoning. As a consequence of his pioneering activities in this direction, he became a member of the Advisory Committee on Zoning appointed by Herbert Hoover when Secretary of Commerce. Mr. Knowles was Chairman of the City Planning Commission of Pittsburgh from 1922 to 1929, and Chairman of the Zoning Board of Appeals of Pittsburgh from 1923 to 1927.

Mr. Knowles was Director of the Department of Sanitary Engineering, University of Pittsburgh, from 1911 to 1920 and in 1929 was awarded the honorary degree of Doctor of Engineering at the University of Pittsburgh. He was Vice-Chairman of the Executive Committee of the Commission appointed by the Governor of Pennsylvania to study municipal consolidation in counties of the second-class in Pennsylvania, and drew up a proposed charter for a federated city to amalgamate over 100 minor political subdivisions in Allegheny County into a Greater Pittsburgh. Mr. Knowles was Chairman of the Committee on Utilities of President Hoover's Conference on Home Building and Home Ownership in 1931. He was a term member of the Corporation of the Massachusetts Institute of Technology from 1924 to 1929. He was a Director of the Pittsburgh Chamber of Commerce from 1922 to 1930; Director of the American Society of Civil Engineers from 1928 to 1930; former Director of the National Conference on City

Planning; Member of the Institution of Civil Engineers of Great Britain, and the Verein Deutscher Ingenieure, Germany; Member of the American Society of Mechanical Engineers; past President of the Engineers' Society of Western Pennsylvania, Member of the American, New England, and Pennsylvania Water Works Associations, the American Public Health Association, the American Academy of Political and Social Science, the National Institute of Social Science, the Boston Society of Civil Engineers, the National Municipal League, and the International Housing and Town Planning Association.

Mr. Knowles was a member of the Duquesne Club and the University Club of Pittsburgh, the Engineers' Club of New York City, the Cosmos Club of Washington, D.C., the City Club of Boston, and other clubs. He was the author of "Industrial Housing," 1920, and many professional papers and contributions to the technical press.

Mr. Knowles is survived by his wife, Mina McDavitt Knowles, a son, Morris, Jr., of Pittsburgh, and a daughter, Mrs. H. M. Schreuder of New York City.

MYRON G. MANSFIELD.

BOOK REVIEW.

THE SANITATION OF WATER SUPPLIES. By Murray P. Horwood, Ph.D., Associate Professor, Department of Biology and Public Health, Massachusetts Institute of Technology. Charles C. Thomas, Springfield, Ill. and Baltimore, Md. Cloth; 6 x 9 in.; XI + 181 pages; 26 figures and 19 tables. $3.00.

As the author of this readable book points out, the subject of water supplies has three essential aspects — engineering, laboratory and public health — all of which need to be appreciated if any one of them is to be mastered. The pattern of the book, therefore, is intended to be such as to include enough of each of the three aspects of the subject to make possible a general understanding of the sanitary problems involved in providing and maintaining water supplies.

After an introductory chapter, "The Rise of Municipal Sanitation and Public Health," which, though interesting, appears to the reviewer to be somewhat wider in scope than the subject matter of the book calls for, there follow chapters on the "Development of Municipal Water Supplies" and "Sources, Uses and Consumption of Water." These two chapters cover in 25 pages the planning, development and maintenance of the collection and distribution works of water supplies; the remainder of the book being devoted to a consideration of water quality and of water purification.

Chapter IV (10 pp.) deals with the "Requirements of a Potable Water Supply', taking up in order the problems of color, turbidity, odors and tastes, hardness and bacterial requirements and ending with a summary of the U. S. Public Health Service Standards. The succeeding 28 pages, constituting, in the reviewer's opinion, the best chapter in the book, deal with "Water as a Vehicle of Disease."

Chapter VI (14 pp.), "The Purification and Improvement of Water Supplies," presents statistical information upon the sources and treatment of municipal water supplies in the United States and discusses the improvement of water quality by distillation, selection, storage, control of catchment area, aëration, liming and treatment with activated carbon. The subject of "Water Softening" occupies the seventh chapter (11 pp.) of the book and outlines the reasons for and methods of water softening including the basic chemical formulation of softening reactions. Chapters VIII (14 pp.) and IX (22 pp.) deal respectively with "Slow Sand Filtration" and "Rapid Sand Filtration." These chapters cover the development of filtration, describe the structural and operating features of filters and indicate the relative fields of usefulness of the two types of plant. Chapter IX discusses in addition the use of coagulants and mixing and settling tanks.

The final chapter (32 pp.) of the book treats of "The Disinfection of Public Water Supplies" and in particular of the use of chlorine and chlorine compounds for this purpose. Attention is given also to superchlorination, dechlorination and prechlorination as well as chloramine in the control of odors and tastes. Brief reference is made to the use of ozone and ultra-violet light. A list of text-books and journals on the subject of water supply and an index complete the book.

In general the choice and sequence of subject matter of the book is well balanced. The section on "Ground Water Supplies" in Chapter II, however, belongs more logically in Chapter III. In the latter chapter, a good deal of space seems to be devoted to the rain gage, and the impression is given that engineering estimates of water yields are based upon rainfall, a dangerous practice even in the absence of direct information on run-off. In the body of the book,— water quality and water purification,—the reviewer misses in particular a discussion of natural, or self, purification, a summary of the permissible bacterial loading of water purification processes, and the presentation of analytical evidence of improvement in water quality accomplished by purification, as experienced in practice. The sanitation of private water supplies might well have received some attention.

The illustrations are well chosen and the text, which is almost free of typographical errors, is attractively set up and printed.

GORDON M. FAIR.

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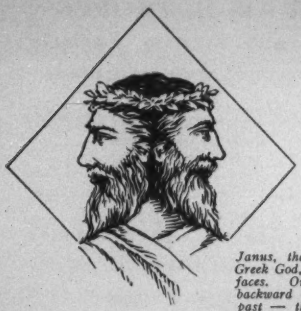

Janus, the ancient Greek God, had two faces. One looked backward into the past — the other looked forward into the future. In these times, industrial progress is made by those who face the future — and take no step backward.

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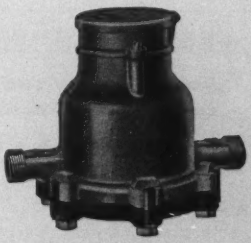

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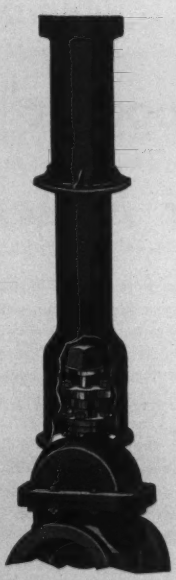

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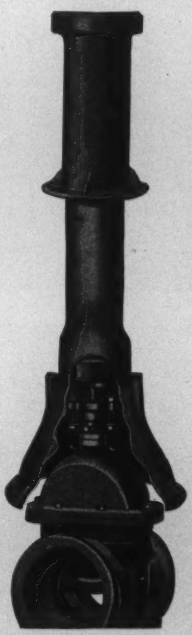

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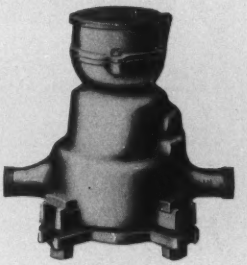

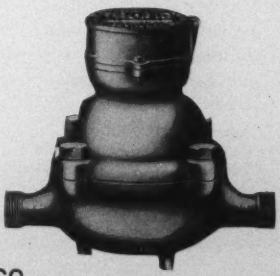

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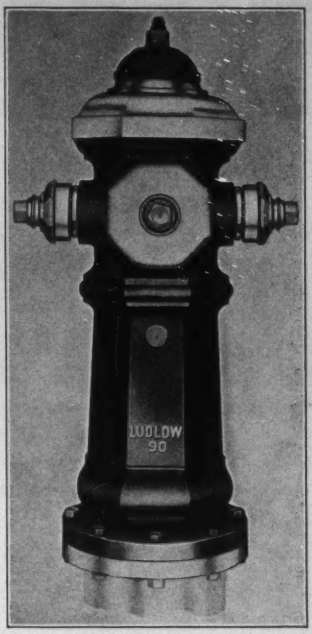

Why has city after city adopted the new Ludlow Diamond Fire Hydrant? The answer is easy. The Ludlow Diamond meets all the requirements of sound long-term investment.

Modern in design, keeping pace with progress, Ludlow Diamond Hydrants installed today will be modern thirty, forty, fifty years hence. Self-illuminating, their beveled reflecting surfaces add new factors of safety, while at the same time improved mechanical design establishes new standards of maintenance economy.

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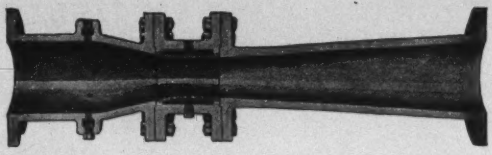

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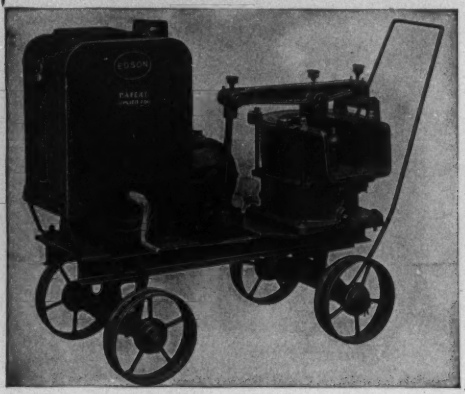

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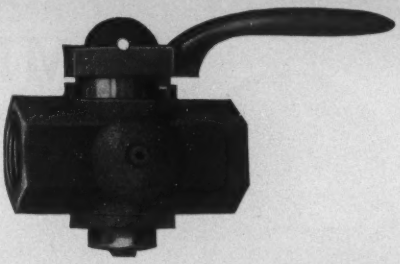

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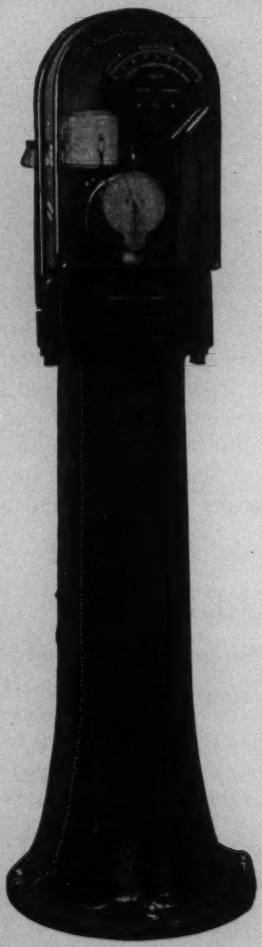

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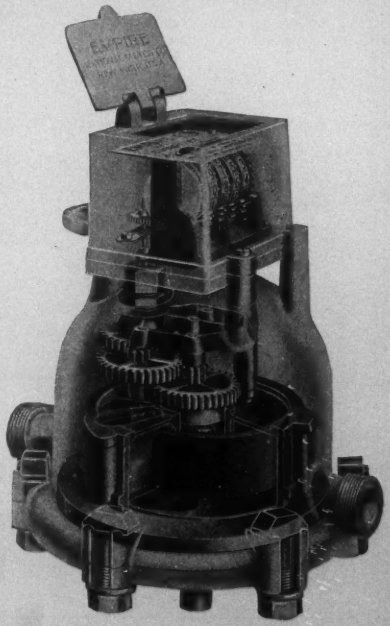

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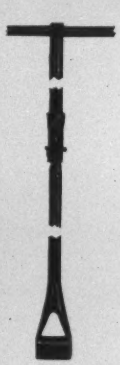
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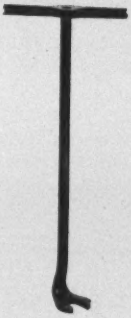
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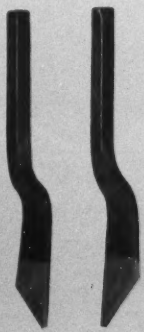
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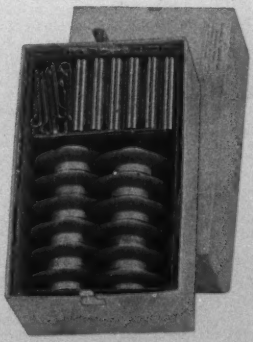
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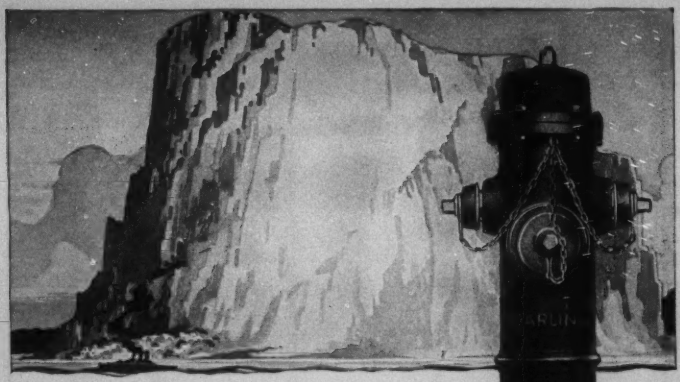

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Also makers of the famous Revolving Double Disc Gate Valve.

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Hydrants and Valves

BUILT TO MEET EVERY EXACTING REQUIREMENT OF WATER-WORKS SERVICE

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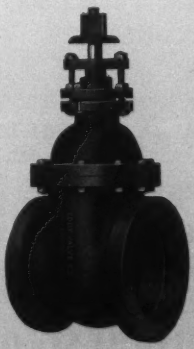
Stems cannot be bent in closing the hydrant.
Nothing can lodge on the valve seat to prevent closing of the valve —
The Drip Rod can be removed without interfering with the hydrant in any manner —
The position of the stem of the hydrant indicates accurately the position of the valve —
Whatever can pass the valve opening will pass the standpipe —
No frost case necessary —
All of these points are explained thoroughly in our catalogue, which will pay you to study.

The Eddy Valve, Too



Has its distinctive and individual features. The double disk gates are free to adjust themselves in different positions every time the valve is closed, thereby keeping smooth and tight faces. And two bronze hooks on the ball loosely engage with the gates to prevent them from spreading at the top. The center bearing gates are forced to their seats with equal pressure at all points. There is a good deal more worth knowing about Eddy Valves. Further details will be sent for the asking.

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The Eddy line of water-works products also includes horizontal and vertical check valves, foot valves, hydraulically operated valves, indicator posts, etc.
All goods made by the Eddy Valve Company are manufactured exclusively at Waterford, New York.

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As compared with the poured joint, in this respect, the superiority of **LEAD WOOL** is apparent.

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Lead Pipe, Tin Lined Lead Pipe, Pure Block-Tin Pipe, Solder, White Lead and Red Lead.

HIGHEST QUALITY SOFT BRANDS

PIG LEAD

CLEAN PIPE LINES

having high coefficients deliver more water and give better fire protection than corroded mains.

High coefficients mean greater delivery in gravity mains and lower power costs in pumping mains.

GENERAL PIPE CLEANING COMPANY

Commercial Trust Bldg. Philadelphia, Pa.

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WATER PUMPING INSTALLATIONS
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SUBMERGED SUCTION LINES
DRIVEN WELL SYSTEMS

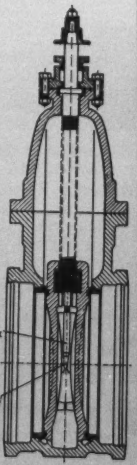
Emergency Work a Specialty

All Types of Pumps in Stock for Rental

141 MILK STREET Phone HANcock 4570 BOSTON, MASS.

VALVES that Are Really TIGHT!

THE positive wedging mechanism in Smith Standard Gate Valves is positive insurance against leakage. These wedges are compound, their sides tapering to function with tapers on the backs of the discs, while their heels function with inclines in the valve bodies, coming in contact with the discs only when the latter have covered their ports and their further downward travel is arrested.



SMITH GATE VALVES
THE A.P.SMITH MFG.CO.
East Orange N.J

THE METER BOX COVER WITH THE *HINGE EFFECT!*

A Real Boon to the METER READER

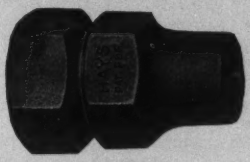
WHEN you buy meter box covers, consider the man who reads the meters and opens hundreds of meter boxes every day. The Ford Type X cover with the hinge effect, *saves time and effort with every meter reading.*

Notice the illustrations above and at the left. The lid may be leaned back as though it were hinged. *No mud, snow or leaves are dragged into the meter box when the lid is replaced. Write for prices.*

The FORD METER BOX CO.
WABASH, INDIANA
WATER METER TESTING AND SETTING EQUIPMENT

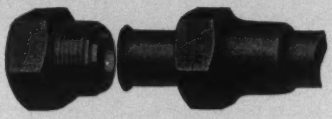
The Hays Copper Plumbing Method

Regular Corporation Stop



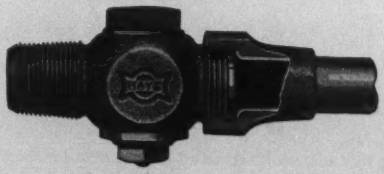
Adapter

In making an installation with Hays Copper Service Fittings the regular Corporation Stops can be used in conjunction with the adapter. It is not necessary to procure new mandrels, as the Corporation Stops are inserted with the regular mandrels, in the usual manner, after which the adapter is attached.



Open View of Adapter

These adapters are made with Female Thread for Increased I. P., Water Works Standard or Lead Flange.

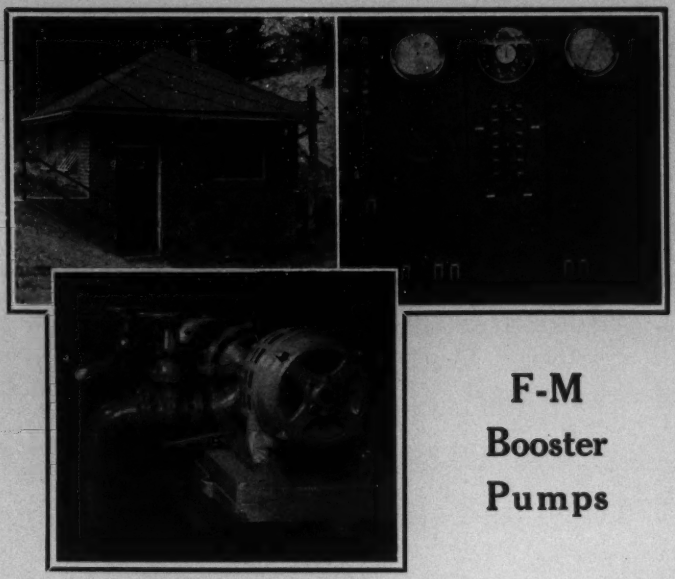


To use standard Corporation Stops with Increased I. P. or Water Works Standard Thread, and where a direct connection of the Corporation Stop and Copper Pipe is desired, the above stop has been designed. (See cut above for sectional view of joint.) These stops permit a Hays 90° seal with the use of regular male mandrels.

Write for complete details of

The Hays Copper Plumbing Method for Water Works and House Plumbing

Hays Manufacturing Co. Erie, Pa.



F-M Booster Pumps

At SOUTH HADLEY, MASS.

Shown above are the exterior of the South Hadley Water Works Pumping Station, the two F-M Motor Driven Centrifugal Pumps installed in the station and the control equipment. The station is located at one extreme end of the town and takes water from a small reservoir under a positive head of approximately 12 or 15 feet and pumps it through the main section of the town to a standpipe at the other end. Both pumps and motors are of ball bearing design, which construction was selected because of the desirable feature of lubrication. The bearings require attention only once a year.

FAIRBANKS, MORSE & CO.

178 Atlantic Avenue, Boston, Mass.

FAIRBANKS-MORSE

PUMPS · DIESEL ENGINES · MOTORS

AN IMPORTANT CONTRACT

We take pleasure in announcing that the city of Newton, Massachusetts has awarded us the contract for furnishing and installing three DeLaval Steam Turbine driven Water Works pumping units with electric generators and all auxiliaries.

Plans and specifications were prepared by Weston & Sampson, Engineers, and Richard H. Ellis, Water Commissioner. Installation photographs, operating data, etc. will appear in subsequent issues of the Journal as the work progresses.

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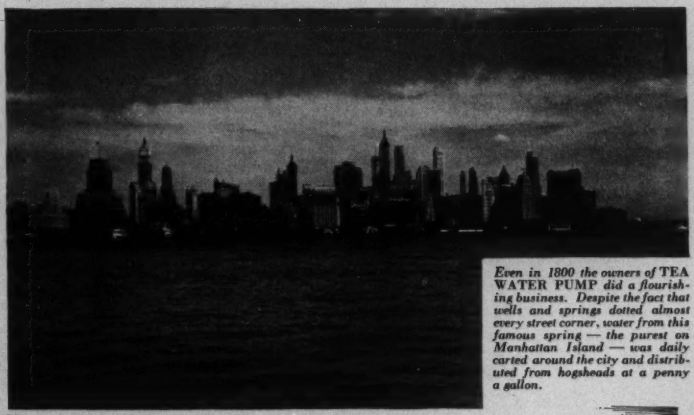
OF NEW ENGLAND
80 Federal Street Phone LIB erty 5993-4 Boston, Mass.

DELAVAL TURBINES AND GEARS
DELAVAL PUMPING MACHINERY

PURE WATER
..BUILDER OF CITIES

NEW YORK *has always*
demanded **PURE WATER**



Even in 1800 the owners of TEA WATER PUMP *did a flourishing business. Despite the fact that wells and springs dotted almost every street corner, water from this famous spring — the purest on Manhattan Island — was daily carted around the city and distributed from hogsheads at a penny a gallon.*

FROM the pioneer days at Smith's Pond . . . Dunwoodie . . . Kensico . . . the name of W & T has been inseparably linked with chlorination history of New York's water supply.

New York chose W & T from the very first, when, in 1914, following exhaustive competitive tests at Smith's Pond, L. I., W & T equipment out-performed all other chlorinators.

Forty-two times in seven years the Water Department of New York has ordered additional W & T equipment—91 units in all. Today from Scoharie to Long Island W & T chlorinators range Gotham's watersheds for more than 120 miles. The original Dunwoodie and Kensico installations, reinforced by 31 W & T Vacuum machines, daily protect the lives of Greater New York's 7,000,000 population.

Unfailing performance, continued accuracy, simplified operation and low maintenance costs justified this standardization on W & T Chlorinators in the eyes of New York's authorities. You can do no better than to follow their lead.

Ask for Technical Publication 38

WALLACE & TIERNAN CO., Inc.
Manufacturers of
Chlorine and Ammonia Control Apparatus
Newark, New Jersey — Branches in Principal Cities

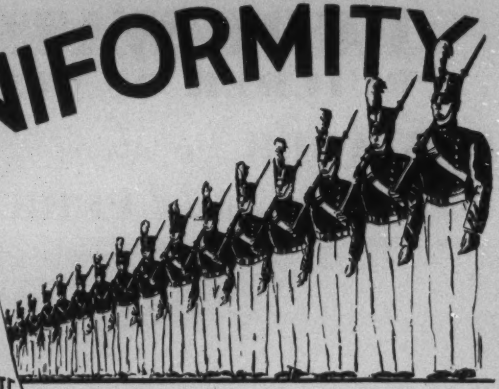
"The Only Safe Water Is a Sterilized Water"

Other W & T chlorinators — 55 more — sterilize private and public pools, disinfect sewage and perform allied services on installations other than those under jurisdiction of the Water Department

8A 41

Are you taking advantage of the R.F.C. Loans for self-liquidating projects?

UNIFORMITY



CONSTANT TESTING ASSURES YOU THAT

WHEN you receive a bag of Hydro-Tite you receive 100 lbs. of material which is exactly like the last Hydro-Tite you used. Every manufacturing operation is carefully inspected and many of them checked by actual test. This care in compounding is only possible when a powdered material is made as we make Hydro-Tite.

Hydro-Tite joints are tight, strong and flexible. They are made without caulking — have a record of over 20 years and save from 50% to 75% as compared with lead. Write for information on any phase of joint making.

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A DEPENDABLE SELF-CAULKING JOINT COMPOUND

Main's Hotcoating for the inside of standpipes and water tanks, will stop all pitting and corroding, and is guaranteed for seven years.

Also

Main's Coverall Salt Air Paint, for the outside of standpipes and water tanks, guaranteed for four years.

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Why you should use GENUINE COREY HYDRANTS

Water to Nozzles quicker than other Hydrants.

Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

Nozzles screwed in — not leaded.

Can be lengthened without shutting off water.

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Positive Drip — cannot freeze.

Standpipe can be revolved quarter turns — Nozzles always in right direction.

Ask for our Catalog "G"

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TROY, N. Y.

DONALDSON IRON CO.

MANUFACTURERS
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CAST IRON PIPE

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Special Castings for Water and Gas.
Also Flange Pipe and Fittings.

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MINERALEAD
For Jointing Bell and Spigot Water Mains

Easy handling, ingot form — Impervious to moisture — Absolute uniformity — Easy melting — Rapid pouring — No caulking — Less initial leakage — Bell holes unnecessary — A saving in cost of material and labor.

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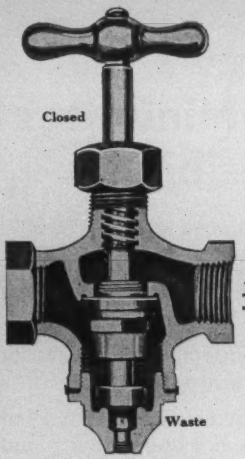
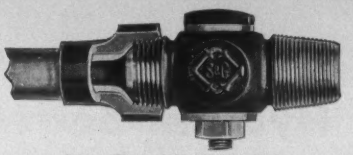
OF PENNSYLVANIA
MERTZTOWN Established 1892 PENNSYLVANIA



Gorham Compression Stop and Waste Cock



Copper Flanged Corporation Stop

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S & D Heavy Pattern Slip Type Service Boxes
Byers' Wrought Iron Pipe
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Service, Roadway and Valve Boxes
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New England Water Works Association

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Meter Rate Sheets:	Single sheet	0.05
	100 sheets, in orange	2.50
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CEMENT LINED SERVICE PIPE
With Specially Adapted Lead-lined Fittings
Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.
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The Mathews Hydrant-Barrel Minimizes YOUR Responsibilities

It is interchangeable with other barrels of same size.

It contains every operating part including the valve seat.

It is instantly removable for inspection or repair.

It makes replacement of broken hydrants quick and inexpensive.

It makes grade-changes convenient and quick.

It does away with all digging or repaving.

It means that no Mathews Hydrant need ever be out of service for more than a few minutes.

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Reg. U. S. Pat. Off.

Send for the Mathews Pocket Catalogue. Learn how only Mathews Hydrants fully answer the problems of accident, frost, rust, leaks, and age.

CAST IRON PIPE—SAND SPUN (Centrifugally Cast) AND PIT CAST
GATE VALVES Reg. U. S. Pat. Off. VALVE BOXES

R·D·WOOD & CO. 400 CHESTNUT STREET PHILADELPHIA
ESTABLISHED IN 1803

How you can save
on each fire hydrant breakage repair

enough to pay for a new hydrant

FIGURES obtained from representative large, medium-size and small municipalities all over the country indicate that the total cost of repairing a broken fire hydrant, including *all* the items, such as excavating and repaving, which should be considered, averages about $75.00 and in many localities reaches $100.00.

This cost can be reduced to an insignificant amount, and striking aggregate savings can be made in your yearly fire hydrant repair expenses, by using

Kennedy SAFETOP
Fire Hydrants.

These hydrants are fully as strong as any other hydrant on the market, but if struck by a smashing impact, the damage is strictly localized to a patented safety breakable section. The broken parts can be replaced in less than 15 minutes, by one man, without excavating or shutting off the water service, and at a total cost of $10.00.

This means that, as compared to the cost of repairing fire hydrants now commonly used, each *SAFETOP repair will save enough to pay for a new hydrant.*

Every water works superintendent should be posted on this important development. Write for full information on the Kennedy SAFETOP Fire Hydrant, how it can be adapted to existing hydrants at low cost, and its many exclusive advantages.

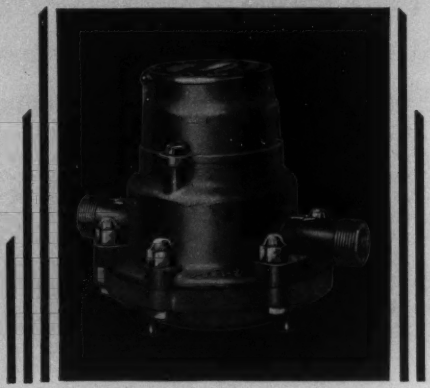
THE KENNEDY VALVE MFG. CO.

Elmira, N. Y.

Branches in principal cities

KENNEDY

VALVES~PIPE FITTINGS~FIRE HYDRANTS



Balanced Design!

The "Plus" Quality in
American and Niagara
Water Meters

Each part in a water meter must be well designed, finely built, if the meter is to give reasonable service. But an aggregation of fine parts is not enough to assure truly fine performance. It requires something "plus." *Balanced design* is essential!

Just as the well-rounded football team will outplay and defeat a collection of opposing stars who "play to the grandstands," so will perfect team-play of all parts in a water meter give the extra accuracy and added life that you are looking for. This you get in American or Niagara Meters.

Back of every American or Niagara Water Meter you buy today, is 40 years of steady development of perfection in each part and in the balance of the whole. You can test for yourself the superior performance of these fine meters, on your next meter order. Write for prices and details.

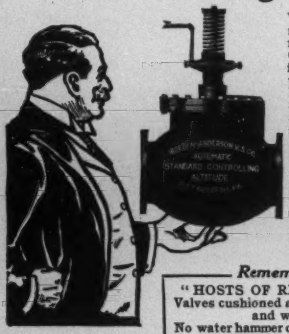
Buffalo Meter Company

Established 1892

2894 Main Street - - Buffalo, N.Y.

GOLDEN-ANDERSON

Patent Automatic Cushioned Controlling Altitude Valves



We have enlightened many a water user in municipalities, in industrial plants and on railroads, as to the adaptability of these Golden-Anderson Valves, and as to their function of SAVING, and of eliminating troubles.

For automatically maintaining Uniform Stage of Water in Tank, Reservoir or Standpipes. Doing away with the annoyance of Freezing and Float Fixtures inside or outside of Tanks.

"Three Ways of Closing These Valves":
1st —Automatically, by water.
2nd—By Electricity, if desired.
3rd—By Hand
May also be arranged to automatically close when a break occurs in the mains. When necessary they may be so connected as to "work both ways" on a single line of pipe. No valves or fixtures inside or outside.

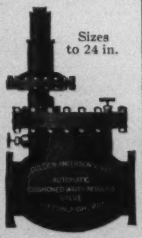
New Haven Water Co. New Haven, Conn. now using
2–24″
1–16″
2–12″
1–10″
ALTITUDE VALVES

Remember!
"HOSTS OF REFERENCES"
Valves cushioned at all times by air and water
No water hammer or bursting mains

30 of these ALTITUDE VALVES sizes, 6″ to 24″ serving the City of Los Angeles, Calf., now.

GOLDEN-ANDERSON
Pat. Automatic Cushioned Water Pressure Regulating Valves

1. Maintain a constant reduced pressure regardless of fluctuations on high pressure side.
2. Perfectly Cushioned by water and air. No metal-to-metal seats.
3. The best valve made for maintaining a constant low pressure where consumption is continuous.
4. Operates quickly or slowly as required — No attention necessary.
5. Positively no hammering or sticking.



Sizes to 24 in.

GOLDEN-ANDERSON
Patent Automatic Cushioned Controlling Float Valves

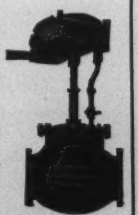
They carry a constant water level in feed water heaters, Tanks and Reservoir by perfectly controlling the flow of makeup water.

Operated by protected enclosed copper float.

Cushioned by both air and water.

Operate without hammering, sticking or chattering. No metal-to-metal seats. Made angle or straightway.

Sizes 1 in. to 24 in.



GOLDEN-ANDERSON
Pat. Automatic Cushioned Water Float Valves

1. Automatically Maintain Uniform Water Levels in Tanks, Standpipes, etc.
2. Instantly Adjusted to Operate Quickly or Slowly.
3. Floats Swivel to any Angle — Most Satisfactory Float Valves Known.
4. No Metal-to-Metal Seats — No Water Hammer or Shock.
5. Cushioned by Water and Air.

Angle or Globe

Sizes to 24 in.

GOLDEN-ANDERSON
Patent Automatic Double Cushioned Check Valve

Sizes to 24 in. Angle or Globe

Automatically prevents reverse flow of pressure. Perfectly cushioned to prevent shock or hammer. Especially adapted for water works to prevent disastrous reverse flow of pressure due to pumps stopping. Arranged so that quick or slow operating may be obtained.

Golden-Anderson Valve Specialty Co., 1325 Fulton Bldg., Pittsburgh, Pa.

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